First Specifications of an Information System for Urban Soundscape

Sylvie SERVIGNE*, Robert LAURINI*, Myoung-Ah KANG*, Ki Joune LI**

*Laboratory for Information System Engineering
Claude Bernard University of Lyon / National Institute for Applied Sciences
INSA - 404 - 69621 Villeurbanne Cedex - France
Email: (Sylvie.Servigne, Robert.Laurini, Myoung-Ah.Kang) @lisi.insa-lyon.fr
**Computer Science Department
National Pusan University
Kumjeong-Ku, Pusan - South Korea
Email: lik@spatios.cs.pusan.ac.kr

Abstract

Sounds are very important in our daily life with a twofold attitude for any citizen. In one hand, when music, sounds are considered as enhancing the quality of life, but in the other hand, traffic noise deteriorates the quality of life. Due to those contradictory characteristics, the new concept of soundscape tries to combine both positive and negative aspects of the auditory environment. Presently, and more and more in the future, any urban planning activities try and must try to diminish noise levels everywhere in the cities and also outside, for instance at the vicinity of airports.

Local authorities daily receive complaints regarding noise. But they generally come from very quiet precincts, and practically never from very noisy zones such as along busy highways. So, it is very important to provide the urban decision-makers an objective tool to compare not only noise levels but also soundscape, and to simulate the auditory impacts of any new urban developments.

The goal of this paper will be to give the first elements of the design of an information system dedicated to auditory information for cities. We will successively described the importance of urban soundscape, the structure of the information system, some element for the visualization of sounds.

Introduction

In urban areas, city noises represent today a great problem. They are a real nuisance for city-dwellers. Noises are caused by traffic, road works, factories, and also by people. So taking into account noises on urban planning should enhance the quality of life of everybody. More knowledge about urban noise could allow to compare different citywards, to reduce noise in noisy places or to simulate auditory impacts of new urban developments. These can be only done by means of noise information and a Geographic Information System (GIS) of a city.

The Lyon National Institute for Urban Engineering (INGUL) has decided to finance a new research program concerning the design of an urban soundscape GIS. This program is a collaboration between several laboratories in computing and urban planning and its objective is to design a prototype system for urban auditory information [I], [2].

The long-term goal (live years) is to design a special GIS devoted to urban soundscape representation, management and simulation. For this purpose a lot of other information is required concerning urban landscape, traffic, and human behaviors. Pieces of information are quantitative but also qualitative. Because of the complexity of the whole phenomenon, we first focus on soundscape representation, integration and visualization and leave simulation aspects for the second phase of the project.

For any city manager it is very important to have an information system for urban sounds and noises. Indeed complaints regarding noises received by a municipality are biased: in very noisy places such as along motorways, complaints are not sent, but in very quiet places, complaints regarding noise are very frequent. So, only a computer system will help any ciry manager to make relevant decision regarding noise.

The goal of this paper will be to give first elements in order to completely specify an auditory urban information system. First the problem of urban sounds will be studied taking their quantitative and qualitative aspects into account. Then first specifications will be given emphasizing conceptual modeling and sound visualization. And we will finish by giving some perspectives for future works.

1. Sound and city

Sounds in urban city are more and more intolerable for city-dwellers. More and more complaints are made about embarrassments due to noises. It is a criterion for quality of life. City managers have taken this social phenomenon into account from several years. They ask for tools which should be able to help them to first understand the situation and then to assist them in policy-making.

Now, there are existing too few works [3], concerning sound and GIS. Some software products are able to give a 2D cartography impact of the sound when, for example when a new motorway is planned. This kind of maps only produces sounds

0-7695-0253-9/99 $10.00 © 1999 IEEE

maps according to quantitative data, i.e. sound levels of urban traffic. These maps show sound impact among space. Now, it is well known that they are partially fit for use and do not allow to propose real action means so as to improve citizens welfare. Indeed these maps do not integrate other sounds sources outside traffic noises. Because there exist a lot of other sounds sources such as human voices, animal noises, and other noises due to economical activities. In addition, to bring a realistic representation of soundscape, it is necessary to take contextual urban architecture into account that is to say land built forms. Building heights and shapes, façade materials, yards, gardens and so on, have a great influence on sounds diffusion.

Another aspect of embarrassment induced by urban sounds is to evaluate people sound appreciation. In fact, sound embarrassment does not only depend on sounds level. Sometimes, a high sound is less intolerable than a low one. There exist flats located above discotheques. In other words for some people, very noisy places are not annoying at all. Embarrassment caused by sound sometimes depends less on sound level than on human feeling according to a certain context. As a conclusion, embarrassment may vary according to people.

Taking into account these sociological and psychological aspects, characterizing urban soundscape leads to define the *auditory identity of a place.* In order to be useful, sound maps must give a more general representation of auditory environment and even *auditory atmospheres* to finally define the *auditory identity of a place.* To define the auditory identity of a place requires also qualitative data so as to give a more human and realistic representation.

It is also important to include the spatio-temporal aspects of the sound. Sound evolves among space and time and the soundscape variation may be very important between, for example, night and day. Sounds maps must no longer be static but dynamic, and perhaps require animation to show sounds evolution.

Today city managers need more information for urban planning. A tool helping them to know, to understand, to qualify and to simulate urban soundscapes will be a new type decision support system devoted to urban projects. The most difficult problem for this tool is to be realistic and relevant according to the complexity of data required, and the necessity to clarify the objectives of urban decision-makers.

2. System specifications

In this paragraph, only basic components of the specifications will be given. For a lot of reasons, this is too early to give the complete and definitive specifications. Here, the detailed specifications will reflect both the main priorities and some exploratory characteristics.

Successively we will study the potential users and their requirements, the kind of data to store and some considerations for visualizing and updating.

2.1. *Users and uses*

As far as we know, the potential users of a GIS for soundscape can be elected officials, city councilors, managers, urban planners, architects, traffic engineers, and city-dwellers and their associations.

And the main priorities are to know more about cities, to detect and to analyze soundscape, and to simulate sound impact especially for new urban development.

Quality of life is today a major concern of people in industrial countries. For elected officials (mayors), it is today an important stake to enhance life quality of city-dwellers as they are also electors. They all need a diagnosis of city soundscape to help them in their decision concerning urban projects, but also to understand better the consequences of sound impact on people behaviors, and evolution of the city.

For urban planners and traffic engineers, it is useful to qualify the city soundscape. Concerning urban projects it is important to understand and to simulate sound impacts so as to integrate a ‘sounds decision criterion’.

Knowing auditory identity of places may help present or future city-dwellers to choose the place where they would like to live. In case of new urban project simulation, they would be able to know the possible consequences of sounds impact on their everyday life.

2.2. *Information versus data*

A lot of various information must be required to characterize a soundscape. Information can be *quantitative (ex:* sounds level) but also *qualitative* to be more realistic (ex: pleasant or not). The numerous information which is needed leads to difficulties, first to identify them as key variables, then to make data acquisition, and to finally model them.

Among others, information required concerns:

- physical description of space: topography, buildings, road networks.. .,
- description of space occupation (sound impact): animals, buildings (ex: school), public places (ex: gardens, parks). ..,
- urban acoustic data (sound level of traffic, variation.. .),
- indicators of sound identity based on socio-economic and psychological information,
- sounds records.

Data acquisition is achieved by several methods such as, collecting data in existing urban databases, sounds measurements and collecting, organizations of surveys (city-dwellers, sites), and tape-recording sounds on various places (typically 1 to 2 minutes).

Information for soundscape is specific because of its spatio-temporal characteristics because sound varies according to space and time. This spatio-temporal aspect must be taken into account for data modeling and processing. In addition sound is a continuous data and requires some field-oriented models [4],[5],[6],[7],[8]. In addition, interpolation models based on sample measures are required to estimate sounds everywhere.

2.3. *Visualization*

Visualization of urban soundscape is done by auditory maps. Maps can be thematic and static or dynamic. They require some graphic semiology especially dedicated to sounds (for instance smiling faces as depicted in Figure 1) for quantitative, qualitative and dynamic data. A dynamic can map show soundscape evolution depending on time evolution (time, day/night, week/week-end, summer/ winter.. .).

Visualization can be seen as the output of different types of queries such as map display of database contents, spatial queries (places and sound identification), and spatial auditory queries (display of the sound record located on the map by mouse).

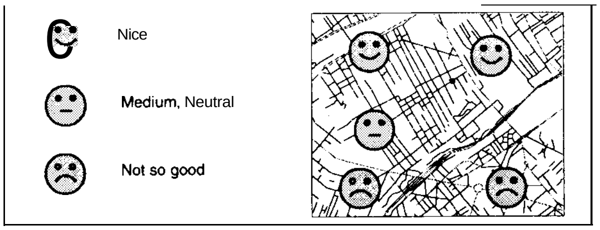

Figure 1. Example of graphic semiology for soundscape description with smiling faces.

In addition to usual queries, we can give three kinds of specific soundscape queries:

- spatio-temporal queries based on field-oriented approach and interpolation methods [9]. A spatio-temporal index of data is also required. An example of this kind of query can be *"what is the average sound in the 12th street at 4 o'clock am?'*
- queries to identify similarity between sounds records based on signal similarity. In these cases, an example of sound is given in the framework of "sounds by example".
- queries based on key-words as criteria.

3. Specifications of the Prototype

Starting from those specifications, we made a prospective work. The goal was to design a 2D cartography of the auditory environment concerning urban areas. In this paper we will not detail completely the prototype, but only give a glimpse of the problems we have to solve.

First, the goals of this prototype will be given. Then some elements of urban acoustics will be examined together with the used interpolation methods. Finally the big problem is sounds visualization which will constitute the kernel of this section.

3.1. *Goals*

As previously said, we intend to define a 2D sound cartography using urban data to bring out noisy places in cities. For this purpose, we suppose that we have characterized data for sound (level, quality...) but we do not know the location of all noise sources.

The goal is to have sounds information everywhere and every time in the city. But obviously this task is impossible. So the idea is to base on some sample points. Based on those samples by means of interpolation methods we will get an approximation of the sounds everywhere and every time in the city. From a mathematical point of view, instead of dealing with ***extensional*** data, we work with *intensional* data.

Another difficulty concerns sound mapping. What is the best semiology to represent noise?

So, for our prospective study to design a 2D cartography of an urban area, we need to:

- collect data for samples of sounds environment (measures, recordings . ..).
- store sound information into a geographic database,
- estimate sound characteristics of all points of the area,
- define map representation of results.

To collect, store, estimate and represent noise data, we need to develop studies on:

- urban acoustics (quantitative criteria) and physio-acoustics (qualitative criteria) to select interesting information for mapping,
- storage and compression techniques for sounds for GIS use,
- interpolation methods in order to select the best method to determine intermediate values of sound between measure points,
- graphic semiology to propose different map representation for sounds.

3.2. *Introduction to Urban Acoustics*

The ultimate goal of an urban sound cartography is to detect noisy places where people are hindered so as to enhance their environment. We said before that people trouble is not necessary proportional to the noise level but depends also on physiological aspects, and that it is unavoidable to try to describe noise not also with *quantitative* aspects but with *qualitative* aspects. For the prototype, only some aspects are taken into account. Two types of quantitative criteria characterize a sound :

- the equivalent continuous noise (Leq) which needs different measures during a day to obtain a representative average of noise environment. The Leq depends on the delay of analysis period and the level of instantaneous noise.
- the three statistical levels:
  1. L_{50} : level of average noise obtained during 50% of the analysis period,
  2. L_{100}, L_{99} : level of background noise,
  3. L_1: level of peak noise.

For our first prototype, we propose to select the following information concerning quantitative aspects to represent an urban noise map, average noise (L_{50}), background noise (L_{99}), peak noise (L_1), trouble: equivalent continuous noise Leq, and distance between persons (speech intelligibility). And concerning qualitative aspects, we have selected noise type, variation during time, soundscape and sound degree (equivalence between the real noise in a place and the expected noise).

3.3. *Interpolation Methods*

The "sound cartography" is based on noise level measure points. So to estimate noises level everywhere and every time in the urban area, it is necessary to use interpolation methods. The most important problem is that noise sources are supposed to be unknown. So acoustic propagation methods cannot be applied and we focus our attention on linear interpolation methods (Figure 2).

The linear interpolation method is far from being correct, but unfortunately as suggested by an acoustic expert, it is the less incorrect.

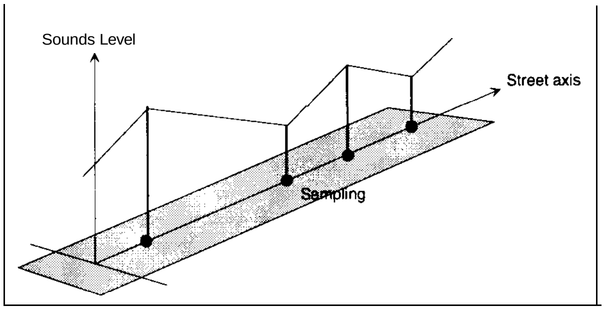

Figure 2. Linear interpolation method for noise evaluation

So we decided to apply the linear interpolation method based on noise measures at each crossroad and along city blocks; but when a more sophisticated method will be operational, it will immediately replace the linear one.

3.4. ***Graphic semiology***

Noise representation is not usual. It is necessary to use the bases of graphic communication. The conventional graphic system is based on seven criteria [10], i.e. size, value (light, dark), texture (color density), color, orientation, shape and representation

Every symbol may give information using various combinations of these parameters: the aim is to obtain a rapid and selective readability. Seven color contrasts exist and two seem to be interested for noise:

- light/dark : gray shade (white -> gray -> black)
- warm/cold : noisy/calm (red -> blue)

There exists a relationship between shape and color. Shape is an expression of "sensibility". So it is interesting to balance shape and color to express some phenomena.

Let us examine several ways to visualize sounds in cities.

a/ Isophonic curves. The first possibility is to use isophonic curves, similar to contour curves, for instance from 65 to 80 db at every km^2 (Figure 3). But due to the presence of buildings in city, this representation is not very relevant.

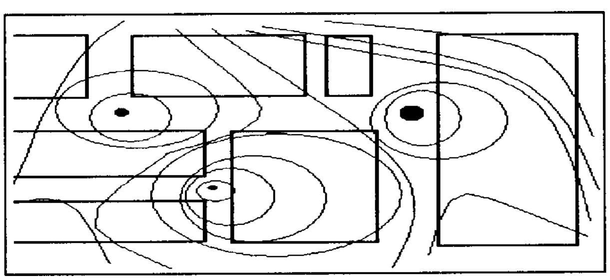

Figure 3. Isophonic curves not taking building barriers into account.

b/ Circles **with variable radius.** To represent noise intensity, circles with variable radius may be used (Figure 4).

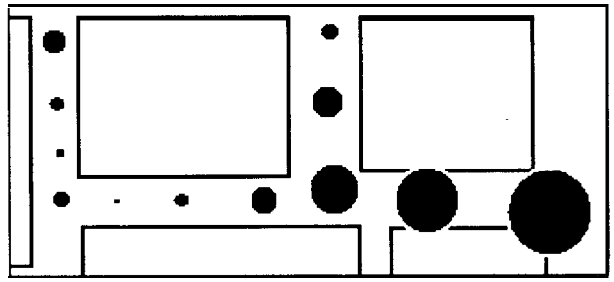

Figure 4. Circles with variable radius

c/ Lines with variable thickness. Lines with variable thickness may be used to represent sound level along roads (Figure 5). This system is perhaps the most readable.

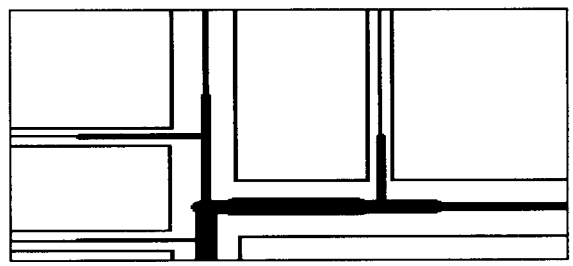

Figure 5. Lines with variable thickness

d/ Colored ranges and contrasts. The aim is to color road, area by area, according to a color scale corresponding to sound levels, using also contrasts. The standard NF S 31 130 may be used for the representation of equivalent level Leq (Figure 6).

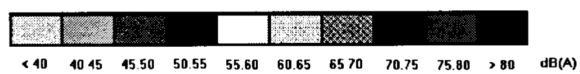

Figure 6. Sounds and associated colors.

e/ Calendar and clock. To indicate time variations, a clock and a calendar may be displayed (Figure 7). This system is interesting, especially when using animated simulation.

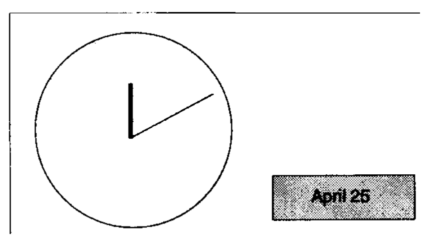

Figure 7. Calendar and clocks

f/ Bubbles. To visualize values and signals, bubbles can be used as exemplified Figure 8.

The study on graphic semiology shows that interesting representations exist to map noise environment. In particular we retain:

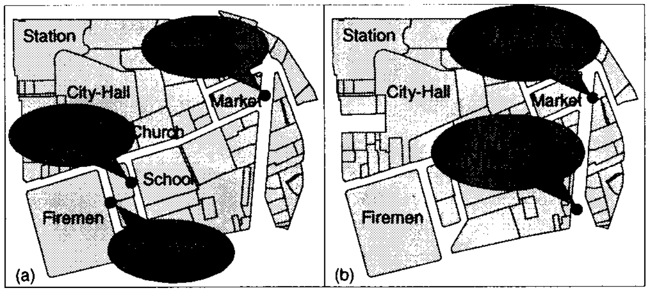

Figure 8. Example of visualization of auditory information. (a) Using bubbles to locate where the measures were made. (b) Location of the tape-recorded auditory signals.

- colored ranges, color contrasts, circle with variable radius proportional to noise intensity and lines with variable thickness to bring out noise variation,
- symbols for qualitative criteria like smiling faces,
- superimposition ,
- calendar and clock to indicate time variations.

A prototype was made to give an overview of the possible representations of the soundscape. We worked on a simplified urban built area of around 10 blocks. Sound levels at each cross-road are supposed to be known and all the sound level points are evaluated by a linear interpolation method. At each measure point is associated a fictitious record. So mouse-based queries on records associated to measure points and modifications of point attributes are possible. The simplified conceptual model [11] is given Figure 9, and the map Figure 10.

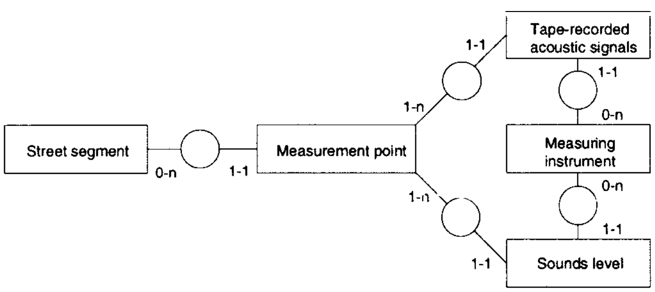

Figure 9. Conceptual model of a prototype of an auditory urban information system

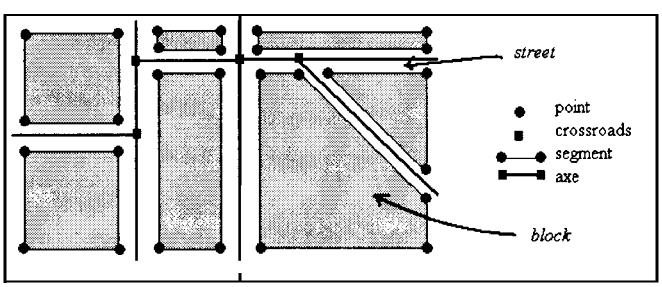

Figure 10. Simplified area with blocks and streets axes

4. Perspectives

In this paper a prospective work on noise and Geographic Information System was presented. The ultimate aim is to create an urban sound geographic database to produce animated maps of urban soundscape, and to simulate impacts, so as to be used to enhance urban planning.

Some propositions for cartographic representation of noise were given. As the locations of noise sources are unknown, it is necessary to estimate sounds levels everywhere using existing measures points. Our study shows that noise estimation is difficult to do and not realistic because interpolation methods would need too many and complex parameters (such as façades description) to give correct results.

In the future, we need to define a very efficient way to store and access auditory urban information by using the field-oriented approach [9] by using special indexing techniques and to define a more efficient visualization system. Finally, we need to explore the storing and interpolating of auditory signals.

References

[1]. Grammon J. (1996) *"Base de données sur l'environnement sonore urbain"*. Master Thesis, INSA, June 1999.

[2]. Servigne S. (1998), *"Towards a Sonorous Urban Information System"*. In Proc. of the COST-UCE C4 Rome Workshop: *"Information Systems and processes for Urban Civil Engineering Applications"*. Edited by U. Schiavoni. Luxembourg: Eur. Corn.., EUR 18325 EN, pp. 191-202.

[3]. Krygier J. (1994), *"Sound and Geographic Visualization"*. In *"Visualization in Modem Cartography"*, edited by A. K. Mac Eachrew, D R Fraser-Taylor.

[4]. Couclelis, H. (1992). *"People Manipulate Objects (but Cultivate Fields): Beyond the Raster-vector Debate in GIS"*, in: Frank, A. U., Campari, I. and Formentini, U. (Eds), *"Theories and Methods of Spatio-temporal Reasoning in Geographic Space"*, LN in Comp. Sci.639, pp. 65-77, Springer.

[5]. Kemp, K. (1993). *"Environmental Modelling with GIS: A Strategy for Dealing with Spatial Continuity"*, Technical Report No. 93-3, NCGIA, Univ. of Ca., Santa Barbara.

[6]. Kemp K. (1997) *"Fields as a Framework for Integrating GIS and Environmental Process Models. Part 1: Representing Spatial Continuity; Part 2: Specifying field variables"*. Trans. in GIS, Vol. 1, n 3, pp. 219-234 and pp. 235-246.

[7]. Pariente D. (1994) *"Estimation, Modélisation et Langage de Déclaration et de Manipulation de Champs Spatiaux Continus"*. PhD, INSA de Lyon, 6 December 1994. 192 p.

[8]. Laurini R, Pariente D. (1996). *"Towards a Field-oriented Language: First Specifications"*. In *"Geographic Objects with Indeterminate Boundaries"* Edited by Burrough PA, Frank AU. Taylor and Francis, pp. 225-235.

[9]. Laurini R. Li, KJ, Servigne S., Kang MA (1999) *"Modeling an Auditory Urban Database with a Field-Oriented Approach"*. Informatica, To be published in the Special issue on Spatial Databases. Invited paper.

[10]. Bertin J. (1983), *"Semiology of Graphics"*, Madison, Wisconsin : University of Wisconsin Press.

[11]. Laurini R., Thompson D. (1992) *"Fundamentals of Spatial Information Systems"* Academic Press, 680 p.