Esquis'Sons ! Sketching soundscapes by using parametric tools: application to the design of balconies, loggias, terraces and corridors of building facades

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Summary
The present project explores in 6 sustainable neighbourhoods in Europe (Germany, Spain, France and Sweden) the sound qualities of intermediate spaces located on the facades of building like balconies, loggias, terraces and corridors. A cross analysis of the physical dimensions of the built space, of the sound environment and of the user's perceptions allows to describe the minimum conditions of existence of these remarkable sound situations (soundscapes). All of this work is compiled in a catalog that is the first tool for sound design of such type of spaces. This catalog is available online on the portal Esquis'Sons (esquissons.com) and geolocalized. This papers shows also how from this remarkable soundscapes, a parametric tool in order to sketch the soundscape of future project has been built. The application use 3D spatial model used by designers and provide a real time 3D virtual sound environment in which users can hear the impact of architectural choices made during the design process. The auralization module is informed by the geometric characteristics of the spatial pattern and vice versa. In other words, this application lets you sketch a space by listening.

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1. Introduction

European Directive 2002/49 EU [1] gives to the member state several tools for environmental noise management in which the Noise Strategy Maps (NSM) represent one the main issue. These maps, in correlation with Geographical Systems Information give an overview of the percentages of people exposed to high levels of noise in a city agglomeration. There are very efficient tools in order to solve the black points (facades exposed to sound levels higher than the limits of the national regulations) and in order to implements noise mitigations at the scale of a city (noise action plans or NAP). Most of the time, it can be seen that these studies are the starting point of a redevelopment project of important sectors in cities and in particular in the creation of new neighborhoods such as those called eco-neighborhoods (see [2]). The works presented in this symposium are quite interesting as they show how it is possible to use this Directive 2002/49 to move from a logic of noise control to a logic of creating a comfortable sound environment. In such projects, acousticians, urban planners and architects are following the same general rules. City planners keep as far as possible the "sensitive" buildings (P.O.I as schools, hospitals, museums, religious buildings, …) from the transportation infrastructure and use noise barriers or "no sensitive" buildings (like parking, industries, shopping malls, …) to improve this protection. Personal cars use is limited and soft ways of transportations are promoted (metro, bus, tram, bikes, walk). Most of the time wide sidewalks are created in order to encourage pedestrians to walk to connect to the closest activities places (shopping, work places, leisure and sports). Indeed, the public's spaces are also re-designed in order to encourage the residents to seat, to rest or to play: small public squares, small private or public parks, playgrounds, benches, etc. Finally, ones can see also that the city planners try to introduce more natural elements into urban development projects with a strong presence of vegetation and a more natural treatment of urban floors: wooden floors, stabilized sands, grass, vegetation, etc.

All these choices have indeed major acoustic consequences by reducing as much as possible the environmental noise (as the road traffic one) and also by promoting and creating news soundscapes. Since the first works of Murray Schaeffer [3] on the soundscape notion and the ones of Jean-François Augoyard, Henry Torgue [4], Pascal Amphoux [5] and Bjorn Hellström [6], the soundscape notion firstly used by musicians and composers is nowadays also used by architects and acousticians in order to caraterize the qualities of the sound environment that we listen to in our everyday life.

Many works question the perceived quality of the sound environment by the inhabitants and show how acoustic and non-acoustic dimensions intervene in those assessments [see 7, 8, 9, 10]. If we go a little further in the logics of development of the city, recent studies also raise the question of silence but also the quality of the sound environment in these neighborhoods [11]. More specifically Kostantinos Vogiatzis [12] and Luis B. Coelho [13] even introduced recommendations for the preservation and the creation of the soundscape in the frame of the noise actions plans (directive 2002/49 EU) for selected neighborhoods in cities in Europe. In other words, the application of the European directive favors the creation or renovation of city districts but it places the city players in front of new acoustic challenges. When the noise of the environment is reduced, what is left to hear? And how can the qualities of this sound environment create a sustainable sound environment for the residents?

2. Ecodistrict and new facades typology

Sustainable logic to design buildings and districts have been creating since the last 20 years new façade typologies. In order to limit urban sprawl and face urban densification challenges, thanks to the development of building techniques, ones can observe that buildings morphologies are creating "residential islets" more or less "opened". On the facades, intermediate spaces to lodgments as larger balconies, terraces, loggias, corridors are designed, most of the time in correlation with a bigger elevation of the buildings. Access areas are requalified with the massive introduction of the "green surfaces" including on vertical surfaces.

The dense habitat partially addresses to the urban sprawl problem, but it still runs some challenges in raising the question of the quality of life it offers through the social link, the concept of privacy, or its link with the surrounding context. Residents can then more easily accept the density, setting aside "the ideal of the house with garden", and accept more easily the density if their lodgement can offer some extensions to the outside as deep balconies, large covered terraces, patios, courtyards, gardens, etc. They are private spaces for entertaining family and friends and to enjoy the outdoors, by gardening, relaxing, eating, reading, playing, etc. Whatever their uses, these intermediate spaces are often heavily invested as part of the housing, while they are at the articulation between the private space of the apartment and the public space of the street. These spaces are more often characterised, from the acoustic point of view, by the qualities of the environment, but also by the uses they are welcoming. The question that arises is the following: how to create outdoor spaces attached to the apartment that can offer enough insulation to have privacy, but also well connected to the outdoor sonic environment in order to enjoy it too ?

Figure 1. Balconies typology in ecodistrict in Paris (Triangle Ile Seguin).

The present project explores in 6 sustainable neighbourhoods in Europe (Germany, Spain, France and Sweden) the sound qualities of intermediate spaces located on the facades of building like balconies, loggias, terraces and corridors. A cross analysis of the physical dimensions of the built space, of the sound

environment and of the user's perceptions allows to describe the minimum conditions of existence of these remarkable sound situations (soundscapes). The qualities of the sound environment that one hears from its balcony depends on a certain number of interrelated factors that have been analysed and described trough online catalogue at : (http://www.esquissons.fr/analyse-croisee/?lang=en) [14]
- the position of the balcony in the façade
- the height of the floor where the balcony is located
- the density of the balconies on the façade and the way they will be occupied by resident.
- the position of the balcony in the islet (closed or open islet)
- the presence of streets with traffic on the outskirts of the islet
- the qualities of the building surrounding areas: green spaces, playground, car parks,..
- the climate conditions in which the neighbourhood is located
- the position of the district in the city: centre town, periphery, in the countryside.

These factors are interdependent and will influence how users will use their balcony. These elements are details that the architect will decide in the first phases of the design process and that will therefore have acoustic consequences on it. It why we focused on this typology of spaces because it concentrates for the architect a set of adjustments that will influence the qualities of the soundscape. In concluding to this brief review, despite real progresses in terms of knowledge and experiences on the issues of soundscape at the scale of the city, the current works are still struggling to make concrete proposals in order to help designers to create new soundscapes.

In another words, ones can say that this work aims to help architects and town planners to understand consequences on the soundscape of their building and neighbourhood designs in order to offer to the future inhabitant a sustainable soundscape. In this sense, a sustainable soundscape is precisely when it is not closed to a single form and it allows resident to enjoy it today and tomorrow. A lot of analysis tools exist but few tools dedicated to design phase exist. It is important to allows designers to sketch the possible future of soundscapes at a stage when a lot of building problems are not solved and are still in progress.

Parametric tool has been developed as a sound sketch tool to assist and support designers in its various working hypotheses in terms of façade compositions and urban composition. The goal is, as it is for the visual sketch, to assist designers by letting them listening the consequences of several architectural choices (sketching sound phenomena and sound effects). This tool is dedicated to the the early stages of the design process in order to help designers to take the right decisions (pedagogical tool).

3. Esquis'Sons : sound sketch tool

Actualy, the analysis of the existing remarkable situations helped us to figure out the detailed specifications of the tool: It had to be realistic with:
- the morphological characteristics of the built environment
- the distance and the elevation from the listening point to the ground (important in situation like housing and balconies)
- the type of urban grounds,
- the uses proposed by the project itself around the listening point,
- distance and elevation from the listening point to the main sources and background noise (transport).
- the presence or the absence of sonic effects, sound signals and sound markers, (sound design)),
- the temporality of the scene created,
- the possibility to locate the sketch in a place and in a culture by selecting specific sources (including upload new ones).
- appearance and disappearance of sounds potentially present within the project,
- appearance / disappearance of elements to reveal the sound space and the built space.
- The three potential "nested" reverbs (the "reverberation" of the balcony itself if any, the first reflections on the nearest facade and the reverberation of the islet formed by the buildings).

The global aim is to provide a sound interface that offers the hearing of the mix manipulated tracks simply with sliders. Or vice versa, these sliders can be considered as the rendering - in terms of mixing – of the architectural design intentions.

3.1 Softwares selection

The Esquis'Sons! application allows to hear live the choices made on a 3D digital model of architecture and especially on balcony, loggia, patio or walkway.

• The 3D modeling software is Rhinoceros 3D for Mac or Windows (by McNeel https://www.rhino3d.com)
• The sound production software is Max / MSP (by Cycling '74 MAX - https://cycling74.com/products/max/)
• The communication interface between the two softwares is built in Grasshopper3D : module Algorithm modeling for Rhino (http://www.grasshopper3d.com)

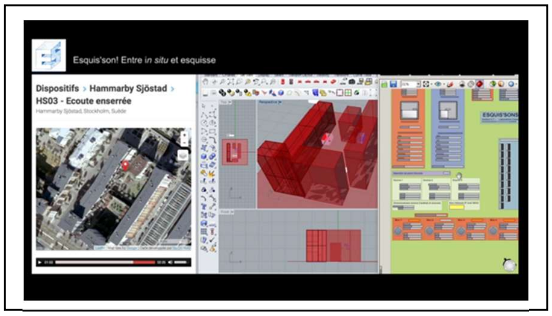


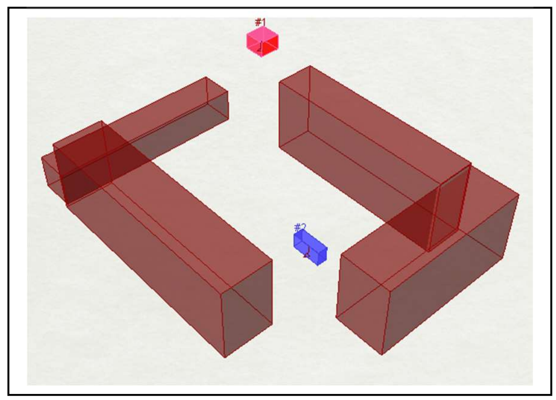
Figure 2. Esquis'Sons ! application (right), connected to 3D model of the space (Rhino) and alimented by real in situ sound recordings (Theo Marchal)

That tool we developed offers the software components (as applications) for this communication. It works in the operating systems that allows the coupled use of Rhino and Grasshopper (for now on Windows or Windows emulation on Apple). Note also that these programs are widely used in architecture schools and agencies, radically changing the principle of operation compared to the old architecture softwares, while opening to the web (Grasshopper community and open source programs). The interactivity between the two programs allows the first one to generate spatial morphologies and the other one to produce sound events. It is managed by an Open Sound Control communication protocol (mainly for its simplicity, speed and python compatibility)..
The main idea of linking these two parametric softwares comes from the fact that they both use the principle of parameters (variable and mainly digital) as background information. The goal then, is to use the information from one to the other, and to reverse the process.
Therefore, a normal user using Rhino during his design process can download and install the Max / MSP module (compiled as an application) that will dialogue with the spatial model trough Grasshopper (free download as a Rhino Plugin).

From the moment when designers declare some basic parameters of geometry, they can hear the sound directly and live, informed directly by the digital sketch : it produces live what we call a "sound sketch".

3.2 Programmation principles

The software solution considers a parallelogram with adjustable dimensions around the listening point. This volume is characterized by a degree of "acoustic closure". The cuboid around the listening point can fit the dimensions of a balcony for example. The wall facing the apartment is characterized by a slider to adjust the porosity and thus the ability to hear on the balcony the sounds



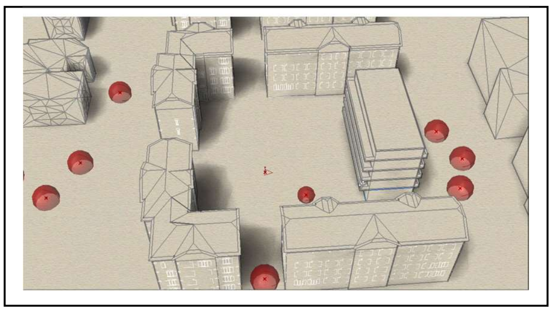
from inside.

Figure3. Esquis'Sons ! Two listening points with their "attached parallelogram" declared in the 3D model (Theo Marchal)

It is possible to assign an absorption coefficient on the declared "parallelogram – balcony" to take into account the capacity of absorption and the quality of materials. The coefficient is generally set on the entire balcony and the value oscillate between 0 (full reflexion) and 1(full absorption - it doesn't say where the absorption is located).

For the building islet, it is possible to declare buildings which can see their length, width and height adjusted. They also can be rotated which will adjust the opening or closing of the islet. It is also possible to import one or more Rhinoceros/Grasshopper geometries as modeled buildings or built environment.
The user can declares "cardinal" soundscapes around the block (in the North, East, West and South), and their "distance" from the block. He could assign to these environments pre-recorded

tracks (neutral and loop) as import his own sounds.
Finally, it is possible to declare 10 localized sources as fountains (different types), playground, ball games, school (courtyard, retracted or classes), cafes terraces, shops, bells, public spaces speaks (languages), steps on different grounds, sounds of nature and fauna (birds, wind in the leaves), electroacoustic sounds (radio, TV, music), mobile phone ringtone and voice, passage of a 2 wheels, bus (- tram – truck) pass, boat passage, etc.
An algorithm has been also introduced in order to play random elements in the sound sketch (as the passing of a car, of a motorcycle, a pedestrian conversation, etc.
For example, at Grenoble (France), architect company named Particule asked for sound sketching in the rehabilation project of the Abbaye district. Here by, is the sound scene as it has been declared in Esquis'Sons ! application (i-e, using Rhino 3D model connected trough



Grasshopper to Max MSP sound generator).

Figure 4. 3D model visualisation with Rhino of Abbaye district, Grenoble - France. Red Spheres are sources declared in Esquis'Sons ! Red triangle, listening point localisation (Theo Marchal).

An urban rumour from beyond the area modelised and composed with identity sounds (such as bells) could be heard according to the islet degree of opening and the height of the listening point.
Finally, Esquis'Sons! includes a "block scale reverb" (developed as a parametric reverb) to make the difference between a islet with mineral surfaces and considered as closed for example and an open one with or without vegetation.

3.3 Script writing principles

The entire script operation consists, starting with the sources positions and two receivers, in the calculation of filters paired with a mix. It's made from geometric data only (distances) calculated and exported from the 3D model in Rhinoceros, trough Grasshopper [15].
The interactivity principle between two software's, one that generates spatial forms and the other that generates sound events, is managed by a OSC communication protocol (Open Sound Control). The idea of having these two software's communicate is based on the parametric principle (variables and math) they both use as their basis information to generate forms or sounds. We then use the information from one to another.

3.3.1 Spatial context

We start by generating or building an urban morphology "context" using a spatial organisation of the sources and listeners designed in Rhinoceros3D via Grasshopper. The numeric parameters used always remain editable. Any geometry can then be implemented in the spatial scene. Then, we place a listening points, for which coordinates, sizes and orientations are defined and van be change on real time

3.3.2 Sound scene

Then, we have to build a sound scene by defining sources with the Esquis'Sons application Therefore, we start by defining the "cardinal" sound environments that constitute the scene sound identity. We assign them a relative distance to the previously created urban morphology. Using the same process, we define until 10 located sources with "Esquis'Sons", which are permeable regarding position, height and size in Rhinoceros / Grasshopper.

For example, distances are acquired between listening points and sources (cardinal and local) from Grasshopper 3D to modulate them. The inverse of the distance, associated to a coefficient is used to choose the gain level for each source, aiming at reducing it proportionally to the distance. This inversion of the distance is also used to inform the low-cut frequency and simulate a decreased perception of the high frequencies caused by distance.

A double measure of the distances enables to lateralize sources (left and right panning). The distances to the source come from the two apexes (left and right) of the triangle generated from the listener. The panoramic ratio is managed by subtracting one distance to the other, and dividing the result by 2. The application interprets this value to pan the sound.

For each source, the potential masks and the disappearance or fading of a source – for each listening point – are calculated using an evaluation of the intersections with the environment. To keep the sound panoramas to which the masks can be applied, a percentage of unmasked sound is generated based on a projections of rays.

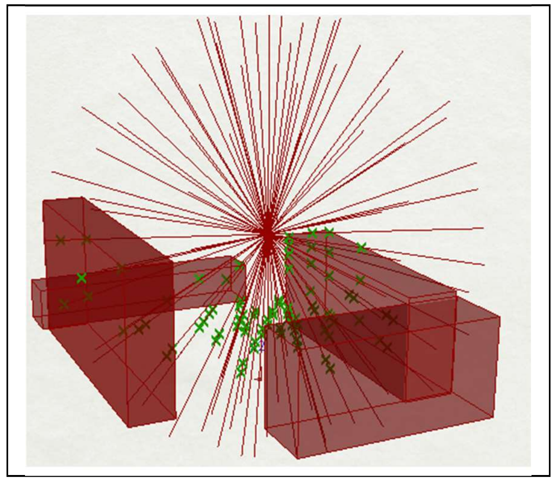
This percentage is then transmitted via OSC to the Esquis'Sons application which manages a value comprised between 0 and 100. This value is then translated in decibels and sets a left and right volume canal for each source. Following this work on sound intensities and frequencies, the sketching tool uses different reverberations related to spatial information.

A reverberation time for each urban block is calculated based on a modified reverberation time calculation to consider its relative opening.
The degree of opening for each block is calculated depending on the listener's position (for example, the sound perception of a built environment is necessarily different if the listening point is at the bottom of a building or at its top). The global volume in each block will be modulated based on this calculation (volume * degree of opening / 100) on which is then based the calculation of reverberation time. The coefficient of general absorption multiplied by the surfaces of floors and façades is needed to calculate this reverberation time. The block specific reverberation is applied to each source depending on its position.

To do this, the distance between each source and the volumes is measured. The result is simplified as parametric bounds related to the size of the block, from the most central to the most peripheral point. The result is used as a percentage of mixing to apply the previously established reverberation. The application also calculates reverberations "inside" the balcony. The goal here is to calculate the volume of the previously determined balcony using Grasshopper, then via the reverberation time formula and an absorption coefficient, to generate the corresponding reverberation.

Finally, a filtering of the external sources that matches the porosity of the balcony sides is required. The porosity of each source through each side of the BLTC is obtained via a ray projection method that allows to estimate the "quantity" of sound passing through. The corresponding filter is then applied to each source and for each side proportionally to this amount of penetration.

Figure 5. Calculation of intersections with environment spherical ray projection (Theo Marchal).



4. Conclusions

Different stages of tests conducted to a development and an improvement of the tool and continues today, especially through educational workshops and with the community of architects. The tool has also been validated and improved by a return of use and field work of the research members that has enabled its development and improvement. In this sense, through the whole process of construction and validation that we have implemented, we tested with other users the realism of the sound scenes produced. We also noted user/designers desires in Esquis'Sons! about the options available when they were testing and try to integrate them. These desires are considered like architectural gestures to integrate into the tool.

For example, we develop specific sound sketch for an urban and architectural study in the district of Abbaye at Grenoble in France. These building have been classified as belonging from the 20th Century Heritage and need to be renovated because they are for most of them insalubrious. Social landlord hesitated to invest to renovate the neighborhood because in this contex, renovation might cost more the destruction – reconstruction. Finally, he opted for an intermediate solution where one of the five buildings forming the islet would be destroyed while the others would be renovated.

The cabinet of architecture then worked on a series of scenarios to find the economic means to preserve what it is considered as an heritage in this district, namely the shape of the urban block, the size of the buildings and their shape. The cabinet proposes then the reconstruction of a new building at the exact position of the old one. The use of Esquissons as a sketch tool was then to demonstrate that from a sound point of view that the sound qualities of the public spaces will be improved in order to be more comfortable for future users of these buildings.

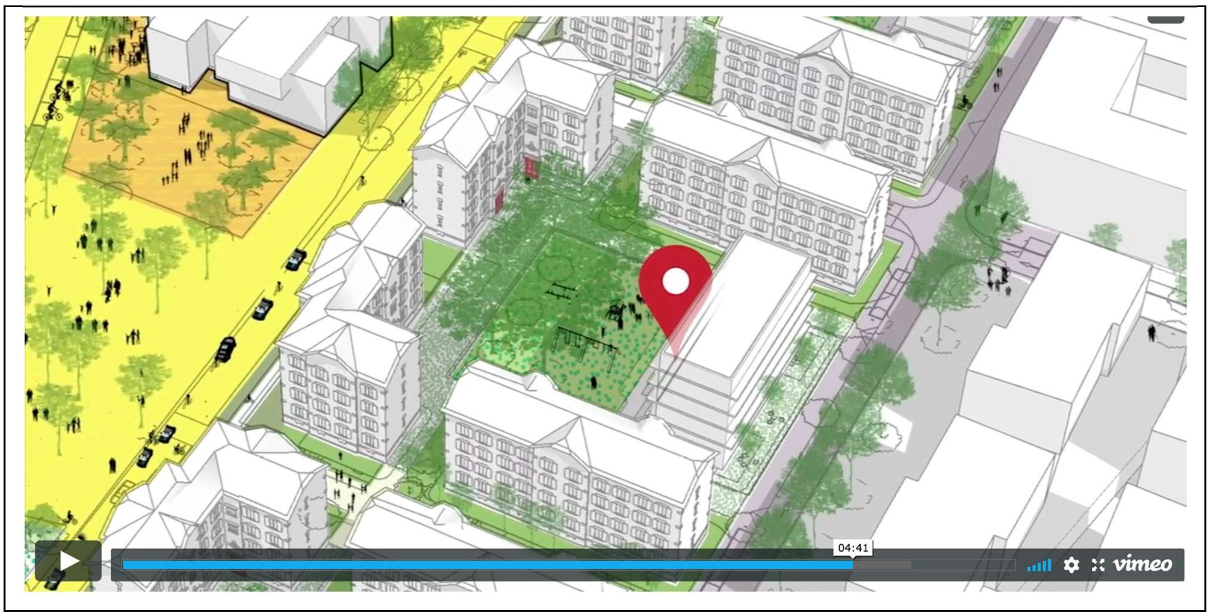


Figure 6. Architectrual Axonometry (Particules Office) visualisation with final Esquis'Sons ! sound sketch for the Abbaye district, Grenoble – France at (http://www.esquissons.fr/tutoriels/1099-quartier-de-labbaye-en-projet/?lang=en) (Theo Marchal)

In fact, the *in situ* analyses and the sound sketch sound track produced are similar and show that the public spaces of the islet core are spaces protected from traffic noise. These spaces are filled with activities present in this place : sounds of nature, conversations, children's games, sounds of first floors activities. As a result, new and renovated apartments overlooking this space are therefore likely to be comfortable in the future.
The sound sketch can be listened at http://www.esquissons.fr/tutoriels/1099-quartier-de-labbaye-en-projet/?lang=en)

This tool - which is not a modelization or simulation tool - is primarily intended to evoke a sound situation. As a sketch, it escapes the question of fidelity of the model and the "reality" of the metrology. Consistency of sonic results is validated by listening and by the "realism" of sound productions thus generated. In this sense, we invite the reader to consult the video "Esquis'Sons! between in situ and sketch "in which we reproduce in Esquis'Sons! an urban configuration in Stockholm (HS03> Hammarby, tightened listening).

The video (https://vimeo.com/146216227) shows the construction of the scene containing the templates of buildings, cardinals sound environments, activities in the block, and a demonstration between the sound recorded in situ and the sound from the sketch. The two fragments are not obviously identical but they are very similar in what it offers to listen: the sound composition of the scene, background, events, and the general ambience of the site.

The sound Sketch tool is therefore at the interface between the physical and rigorous simulation of phenomena and the sound recording expertise. At this stage of development, either from a researcher or an architect designer, the tool is able to open a discussion between the designer and "its" building by the production of these sound small scenes. The sound fragment created from the scene should not be considered only as an image used in a contest (like photo-realistic rendering for example), beyond that, it expresses the "sound answers" to real architectural questions. By adjusting the sound, the designer adjusts some dimensions of his project. Ones can say then that here, **the sound sketch architecture**

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