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# Using 3D city model platform for the analysis of Andorra's Soundscape

Rosa Ma Alsina-Pagès(1), Marc Vilella(2), Marc Pons(2,3) and Robert Garcia Almazan(1)

(1)Grup de recerca en Tecnologies Mèdia (GTM), La Salle - Universitat Ramon Llull, C/Quatre Camins, 30, 08022 Barcelona (Spain) , rosamaria.alsina@salle.url.edu

(2)Observatori de la Sostenibilitat d'Andorra (OBSA) , AD600, Sant Julià de Lòria, Andorra, mvilella@obsa.ad

(3)Andorra Innovation Hub, Actua Innovació,, AD700, Escaldes-Engordany, Andorra , marc.pons@actuatech.ad

**Abstract**

In a SmartCities world, with the citizen in the center of all the decisions, the measurement of environmental noise cannot be limited to provide an equivalent level captured over a certain time in a place of interest. By means of WHO reports and other studies, we know that the type of noise (traffic, anthropomorphic, industrial, etc.) has a different impact on people and that it is important to identify the source of the measured noise levels. In order to facilitate this work for the competent authorities, in Andorra a 3D City model platform is used to visualize acoustic measurements carried out at three strategic points in the country. The platform represents the measured noise differentiating the type of noise, the equivalent acoustic level it is providing and the salience of the event with respect to background noise by means of the calculation of the Signal-to-Noise Ratio, providing a wider and more complete amount of information to allow to decide policies to minimize the impact on people.

Keywords: noise monitoring; anomalous noise event; 3D model; recording campaign; urban soundscape

## 1 INTRODUCTION

Acquisition, processing and interpretation of sensed data is a recurrent task among scientists and analysts. The whole process usually involves a set of theoretical knowledge, complex math algorithms, system patterns and data transformation that lead to the final results and conclusions, generally addressed to other professionals on the same fields of knowledge. There are some other scenarios, however, where the final target of the research may not have a scientific or technical background, and results are intended to be used as support for policy making, awareness raising campaigns or community engagement. In this context, results showcase must be designed to provide more understandable information [8] other than just tables and complex charts, and experiment with alternative visual and dynamic representations, such as animations or time-lapses, moreover if this visualizations are updated in real-time whenever an interaction triggers any parameter change.

The CityScope Andorra [4] is a framework developed by the MIT City Science group in collaboration with Andorra stakeholders, such as the Sustainability Observatory of Andorra (OBSA), intended to help non-experts engage in conversations through visualization of mobility patterns, based in projections on a 1 x 3.15 m 3D topographical model of the country's capital. The same concept has already been exploited to project an interactive overview of the rooftop photo-voltaic potential in Andorra buildings [7] and generate a discussion on the viability of public subsidies policies or organize workshops with local schools[1]. In Figure 1 we can observe the interactive projection in a 3D surface of the rooftop photovoltaic potential in Andorra buildings.

One of the goals of the Andorra Government and the municipality of Escaldes-Engordany is to create a system of real-time monitoring and data integration of several sources of information to inform about the urban dynamics such as traffic and pedestrian behavioural patterns, energy consumption and environmental pollution, among others. The recording campaign and analysis presented in this study permitted us to explore the potential to integrate and cross noise information of different locations of the city in order to better understand what are the

[1] https://youtu.be/FdUKJtJd9ts

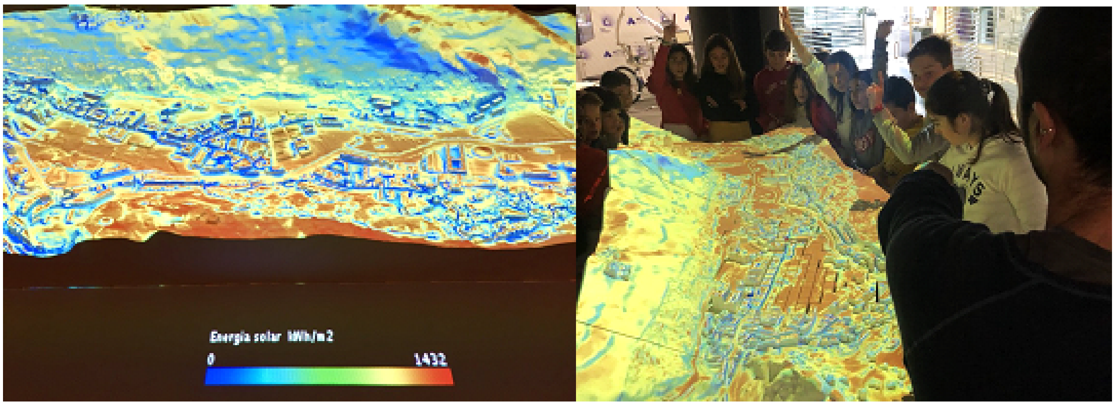



Figure 1. Interactive projection in a 3D surface of the rooftop photovoltaic potential in Andorra buildings.

different sources that are impacting the most the citizens and tourists, and what are their spatial and temporal dynamics. First, the inclusion of this kind of information in the integral "single-view" system of the city can help us to better understand the most important drivers and their dynamics that led to an increase of the noise pollution. Second, this data analyzed together with the different sources of information can provide relevant results to design more suitable policies, measures and urban interventions to reduce noise pollution in the areas where a higher number of citizens and tourist are exposed to, and help in the objective from both the Government and the municipality to increase the quality of the environment and the welfare of these groups [5, 3] Further work will be devoted to develop a longer measuring campaign deploying in parallel other devices such as cameras to apply computer vision to continuously record metrics about the events that occurred during the measurements periods and spanning a greater period to capture other dynamics such as day-night and inter-daily variability.

This paper is structured as follows. Section 2 gives details of the acoustic data collection and processing, and in Section 3 works on the visualization of the measurements conducted. Section 4 states the conclusions and the future work likes of this paper.

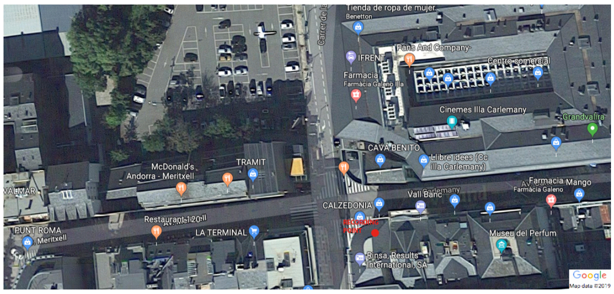
## 2 REAL-OPERATION ANDORRA ACOUSTIC DATA

In this section we describe the areas of the three measuring locations in Andorra la Vella and Escaldes-Engordany, together with the reasons that guided the choices, mainly related to the results of preliminary analysis with automatic level meters deployed in several critical locations in the country.

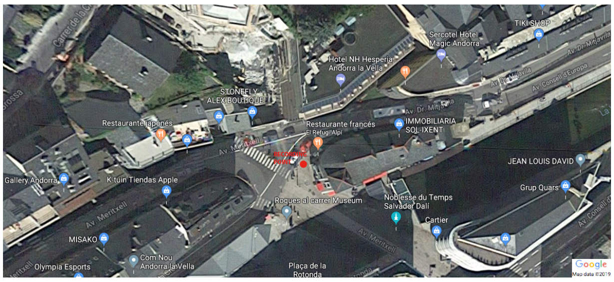
### 2.1 Locations

The selected measuring locations correspond to three important nodes in terms of volume, both for pedestrians or for vehicles. Location (a) (see Figure 2a) is the connection between the 3 main country's roads in the capital [5, 3], with the highest traffic congestion experienced at rush hours. In this area the main sources of noise are mainly expected to be cars. This is expected to have constantly high levels of noise and a lower variability in terms of contributing sources compared to other areas. Location (b) (see Figure 2b) is the intersection between CG-3, the road leading traffic from the capital to the north valley, with the main pedestrian and commercial axis, one of the most frequented points by tourists. In this area the mix of potential sources of noise should be higher, as should the variability of contributing sources of noise in different days or during the day, increasing its interest to be mapped. This location is of additional interest due to its recent transformation into the biggest pedestrian zone in the country. Location (c) (see Figure 2c) is also the intersection of an important road and the pedestrian axis, sharing the same interest for the study as (b). Compared to area (b), in this case the axis is not fully pedestrianised but with an intervention of reducing and slowing the traffic. In this case, the variability of the sources should also be higher during the day. In this case, the impact of two different types of urban intervention is expected to produce different noise dynamics in the area. Thus, these 3 locations were chosen to analyse noise source identification. Furthermore, these will be most probably the places to prioritize future interventions and mitigation measures.


(a) Ctra. de l'Obac / Carrer de la Unió




(b) Av. Carlemany / Carrer de la Unió




(c) Av. Meritxell n$^{o}$73

Figure 2. Images above show the three places where the recordings took place from a satellite perspective from Google maps (Map data: Google 2019). The red dot in each picture indicates the place where the recordings were conducted.

### 2.2 Types of Events

The types of noise of each area have been analyzed to evaluate common events and noise dynamics. In order to classify them, four categories were decided by the OBSA and Actua. Traffic played an important part in the decision, so a *Vehicles* category was required and it was the one with most of the labels. Besides *Vehicles*, already expected to be one of the main sources of noise in all three pilot areas, three other classes were considered in the analysis. *People*, as any noise made by persons, because two of the three pilot areas are highly frequented places for tourists, with crossing points for pedestrians (b) or half-pedestrian (c) areas. In this line, *City Life* class, as any noise taking place in an urban area but omitting traffic noise, has been also used due to expected noises coming from urban elements like traffic light emitters or street music. Finally, some construction works were carried out in places near to the measuring pilot areas, so the *Works* category was also considered.

- *Vehicles:* It is understood as vehicle all noises coming from any mean of transport, not necessarily having an engine.
- *Works:* All noises related to construction jobs.

- *City Life:* Any noise taking place in an urban area excluding vehicles.
- *People:* Any noise made by a person.

The authors refer the reader to [2] for the details of the events analysis, and to find the list of all the labelled items included in each category.

### 2.3 Analysis of the Real-Operation Audio Collected

In this section, we describe briefly the measurements conducted over the raw acoustic data to be visualized. The duration, the equivalent level $L_{Aeq}$, the time stamp and the Signal-to-Noise Ratio (SNR) are the four evaluations needed to proceed with the conversion of the information to images.

- **Duration:** It is evaluated in fractions of second, and corresponds to the time that the visualization will spend to show its values.
- $L_{Aeq}$**:** It is the equivalent continuous sound level in decibels, equivalent to the total sound energy measured over a stated period of time and is also known as the time-average sound level [1].
- **SNR:** It is defined as the relation between the power of the noise event being evaluated and the previous and posterior RTN power of that given event. The following equation explains how it is calculated [6].

$$P_x = \sum_{t=1}^{N} \left( \frac{x(t)^2}{N} \right), \tag{1}$$

where $N$ is the number of samples and $x(t)$ is the event we want to calculate its power. Once this is done, SNR is computed as stated in its definition.

$$SNR = 10log_{10} \left( \frac{P_{NE}}{P_{RTN}} \right), \tag{2}$$

where $P_{NE}$ matches the noise event power and $P_{RTN}$ stands for the previous and posterior RTN to that event. It is to take into account that when calculating both powers, it is not strictly necessary for $N$ to be the same size, since it is a summation that will be divided by N in the end. Furthermore, it can observed that some events will have a negative SNR. This can happen due to high traffic noise that makes an event irrelevant despite being clearly audible.

There is a large amount of events with a negative SNR value which can either mean that the surrounding vehicle noise was louder than the labelled noise or that the event itself was very weak, despite they were labelled as heard. Whatever the reason, these events are not relevant in the specific moment they took place as they do not represent an impact on humans.

## 3 METHODOLOGY AND VISUALIZATION

In this section, we detail the transformation of the collected data into its proposed visualization. The proposed visualization represents all captured sounds as wavy circles. Each circle is drawn with multiple lines producing displaced waves and giving a more dynamic feeling. All parameters of a each circle depend on a different sound attribute, where the color represents the sound's category, the radius represents the equivalent background noise level and the ripple amplitude represents the SNR. Two different approaches have been considered (Figure 3); in the first case the wave's origin is centered in the circle's radius distance, while in the second case the ripple is expanded and the minimum crest matches the circle's radius distance. Despite the first approach looks more balanced, second approach produces a less chaotic and clumsy scene when combining multiple circles to represent different overlapping sounds.

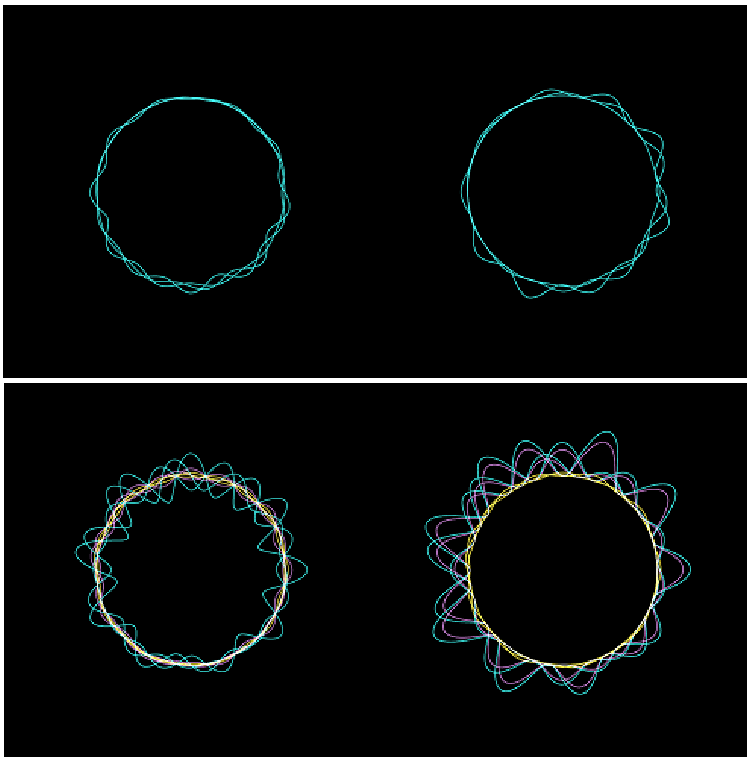


Figure 3. Sound representations with wavy circles

Any SNR bigger than 3 dB would be represented by a wave with an amplitude more than twice the radius of the circle. Being sound events susceptible to reach more than 20 dB, visualization would get out of 3D surface bounds and become totally useless in terms of interpretation. To overcome this limitation, the SNR representation is downscaled to a limited range of amplitudes, to the detriment of the real ratio between noise and sound levels.

Another limitation comes with negative SNR. A proposed solution, shown in Figure 4, could be to represent positive SNR as outside ripple and negative SNR as inside ripple, being the ripple's amplitude bigger as bigger (negative) is the SNR. While this solution represents all recorded sounds, it may introduce a cognitive bias and create confusion in order to understand the impact of very low level sounds.

The visualization is developed in Processing[2], a visualization playground that uses an extended subset of Java language and is focused to visual arts and multimedia. Processing allows full control on graphics usage and has dozens of libraries implemented to work with IO components, computer vision, timing control or multiple file types. The input data for the simulation is a CSV file with a record for each one of the captured sound events, ordered chronologically. Every event is defined by 4 fields, which are common with the list section 2.3:

- ANE: Categorization label for every sound event, corresponding to one of the 4 groups. Labels are

[2]www.processing.org

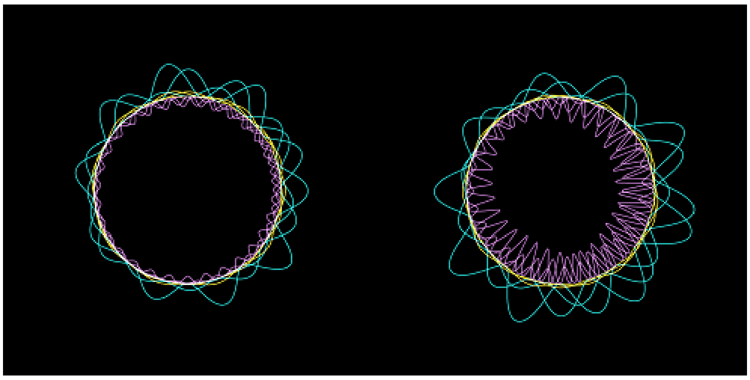


Figure 4. Proposal of representation for negative SNR representations.

grouped in a more generic category to avoid an oversaturated representation.

- SNR: Signal-to-Noise relation in dB of the event over the road traffic noise (RTN).
- $L_{Aeq}$: Equivalent noise level.
- TS: Timestamp of the event capture in the format hh:mm:ss,d. Even if the resolution could be higher, a decisecond was chosen as it was considered enough for representational goals.

Table 1. Sample of the input data

| ANE | SNR | LAeq | TS |
|---|---|---|---|
| TRCK | -8,359 | 66,3835322 | 00:07:45,3 |
| RTN | 0 | 64,8430047 | 00:07:46,1 |
| BRAK | -9,655 | 65,694417 | 00:07:46,6 |
| CMPLX | -6,529 | 67,479711 | 00:07:46,9 |

The input data is loaded during the visualization initialization stage. While a stream loaded by chunks would make more sense in a real-time animation, the input data is actually a preprocessed file with grouping and corrections applied beforehand. Loading the whole file at once is an easier approach in terms of data architecture, that implies few extra benefits such as global statistics and the possibility to control the timeline.

Figure 5 shows the final visualization, a projection of different animated circles located on the 3D surface at the spot where they were measured, and varying their diameter and ripple's amplitude depending on the sound measurements at each instant. No controls are provided at the moment other than stopping and resuming the animation, but simple timeline control options are on the roadmap in the short term.

## 4 CONCLUSIONS

In a noise measurement system with source identification, it is crucial to be able to clearly and accurately distinguish the origin of sounds. But it is equally important how you show your results to the public, since the measurements you take are often not easily understood by the general public.

Scientists and technicians may be often worried about not displaying the whole set of numbers and correlations, but to develop a simple visualization is a key aspect when spreading research results to non-specialist public.

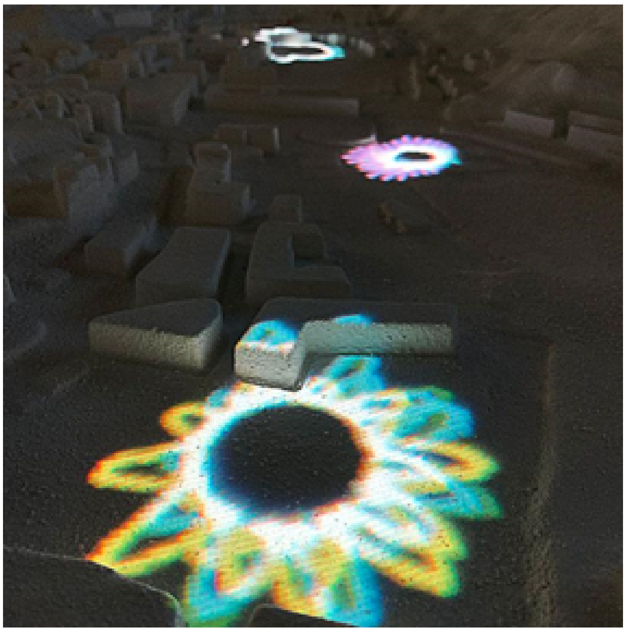


Figure 5. Sound circles on the 3D model.

Proposed visualization does not provide a deep understanding on noise effects to the population or the environment, but gives a big picture on sound events through colors, shapes and sizes. This information can be shared easily with kids, politicians and non-technical audience and allow them to compare where, when and what is happening in their city.

Having this kind of easy-to-understand visualizations on a 3D model of the city, where they can be spatially and temporally crossed with other sources and layers of information, has a great potential to foster interpretation and discussion about the impact of noise pollution events and sound landscapes on the city. This approach could help to collaborativelly understand and raise awareness in differnt types of stakholders as well as help to explore and discuss potential measures and interventions and support decision-making processes or promote social and behavioral changes of citizens.

Future work of this project focus on the implementation of the automatic class detection system, which is already working in other environments with two classes. The second of the future lines is the proposal for real-time operation with a network of sensors deployed in Andorra and Escaldes Engordany.

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