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MULTIDISCIPLINARY STUDENT PROJECT FOR THE SOUND SYSTEM OF A MEDIEVAL CITY

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ABSTRACT

This paper presents the pedagogical approach, results, constraints, contributions and limits of a multidisciplinary student project. This project brought together historians, computer scientists and acousticians from le Mans University and students from the sound design master of the School of Art and Design (ESAD TALM) in association with the city. One project consisted of developing original outdoor sound systems. In connection with the ESAD, two students from the National School of Engineers of Le Mans (EN-SIM) have devoted their 5th year project to this subject. In particular, they developed a stereo pair of vibrating panels to play battle sounds as well as simple directional sources, before installing these prototypes and professional systems *in situ*. A presentation of the devices was made in front of the elected officials of the city one and was appreciated. This project has been very enriching for engineering students in terms of collaboration with students and teachers of other disciplines. However, it highlighted some difficulties in this collaboration and the gap between the expectations of the sponsors and the potentialities of a student project. Secondly, it was quite poor from a scientific point of view, the part of management and technology being essential.

1. INTRODUCTION

The regional program Research Training Innovation Western Creative Industries (RFI OIC) of the Pays de Loire region proposed in 2018 a multidisciplinary student project to the Universities of Nantes, Angers and Le Mans. In the frame of the Training part of the RFI, the idea of this project was to make a challenge between mixed students teams in terms of skills and practices. The subject remained to be defined by each local management staff. The RFI brought an administrative and financial support.

At Le Mans, the project brought together historians, computer scientists and acousticians from the university and students from the sound design master of the School of Art and Design (ESAD TALM) in association with the city. It was decided to develop some tools to highlight the Roman and medieval city of le Mans, called Plantagenêt city (see expe-lemans.fr). A first project, decided by the team of teachers in collaboration with the city, consisted of a sound path based on geolocalization with smartphones and headphones. The second one was an outdoor sound path

with original sound diffusion prototypes. In both cases, scenarios, contents and if possible technological tools had to be developed by students. Acousticians were involved only in the second project in order to develop outdoor original sound diffusion systems.

Next sections describe the context of the project, the work realized by students, the final results in terms of rendering, and an assessment of the project.

2. CONTEXT

A few meetings between teachers, RFI leaders, and representatives of the city culture departement took place between april and september 2018 to define the project. During these meetings, following points were defined and clarify the context of the project.

2.1 Expected results

First, it was decided to develop some tools to highlight the Roman and medieval city of le Mans and present them in front of elected members of the city and press. A positive test would allow to use these tools during the summer tourist period and to make a second challenge to improve them and develop new ones. To sum up, the tools developed had to be operational and convincing.

2.2 Adequation with Educational constraints

Secondly, an essential question was to define which students could participate to the challenge in terms of skills and schedule. The RFI project has to match temporally and pedagogically with the requirements of the trainings. Majority of involved students having internship beginning from january to april, the project duration was reduced right from the beginning to 4 or 6 months versus the students.

Concerning Acoustics, the schedule and educational requirements prevented unfortunately to use the skills and abilities of Le Mans University International Master's Degree on Electroacoustics (IMDEA) students. Only students from the National School of Engineers of Le Mans, even not specialized in electro-acoustics, were considered able to answer to these constraints in terms of training and schedule. Thus, the subject was proposed to these students and only two of them devoted their 5th year project to this subject. One additional student of the master "Acoustique

de l'environnement : Transport, Bâtiment, Ville" had in charge the evaluation of the regulations in terms of noise to provide the sound levels target for the electro-acoustics prototypes.

There was finally a single team working on the project made of 15 historians, 6 sound designers, 2 informaticians and 3 acousticians.

2.3 Work sequences

The sequences were the following:

- september: proposition by historians of stories and related places to work on in the Plantagenêt city.
- october: bibliography by acousticians on sound systems for outdoor and museum type applications and noise regulations.
- october 25th: official kick-off meeting of the project with involved participants and external specialized contributors in the domain, opened to public.
- november and december: choice of 3 places in the Plantagenêt city with corresponding scenarios. Several visits of the Plantagenêt city with the city cultural services to evaluate the real conditions of installations and use. First works on sound system prototypes at the university.
- january - february: realization of prototypes at the university.
- march : installation and tests of prototypes in the city. Demonstration to the elected members on march 18th.

Next section describes the work made by students.

3. REALIZATIONS

3.1 Experiment sites

Three sites were chosen for the implementation of experiments, but we focus in this paper on 2 sites (the third one using classical diffusion):

- Guillaume the conqueror's (GTC) fortification (figure 1, red point named *Muraille GLC*): this fortification is on the edge of the Plantagenêt city and is separated from a quite busy road by a small garden (figure 2). The idea was to fit the garden with a sound system close to a bench facing the fortification in order to play battle sounds.
- Robert Doisneau's (RD) house (figure 1, red point named *Maison suspendue*): this house was immortalized by the photograph Robert Doisneau. The aim is to install a sound shower system below the house located at 5 m from the ground in order to emit children sounds for instance (figure 3).



Figure 1. Chosen sites (in red) for experimentation.

3.2 Technical specifications

The sound system were wished to be installed outdoor. At the beginning of the project, the duration of use (demonstration for one day or more) was not defined. Therefore, the sound system had to be waterproof and protected from thefts. The electricity supply should be provided by connections in the Plantegenêt city. Moreover, the sound system should be ideally triggered by the passing of people in a street or by push-buttons.

3.3 Noise regulations and targets

The aim of a project of Master 2 "Acoustique de l'environnement: Transport, Bâtiment, Ville" was to study the regulations in terms of noise and to provide sound levels target for the electro-acoustics prototypes.

Emergences of 5 dBA are tolerated during the day (7h-22h) and 3 dBA during the night (22h-7h). However, these emergences values are integrated on the whole period and not on short periods of a few minutes. Therefore, emergences can be greater punctually, but should not be too far from the emergences to avoid disturbing neighbours, in a generally calm environment.

For the RD's house, some fullband equivalent sound level measurements integrated on 5 minutes indicate a level of 52 dB (33 dBA), indicating a low level low frequency noise. With active sources, a sound level around 60-65 dB should be enough to understand messages provided by the sound system and not disturb neighbours located at 2-3 meters. Therefore, a really directive sound system, but not powerfull, had to be used.

For the GTC fortification, these values reach 71 dB (53 dBA) at point 2 (figure 2) and 70 dB (54 dBA) at point 4, the nearest from the bench where people sit. In this case, a sound level around 85 dB should be enough for listeners

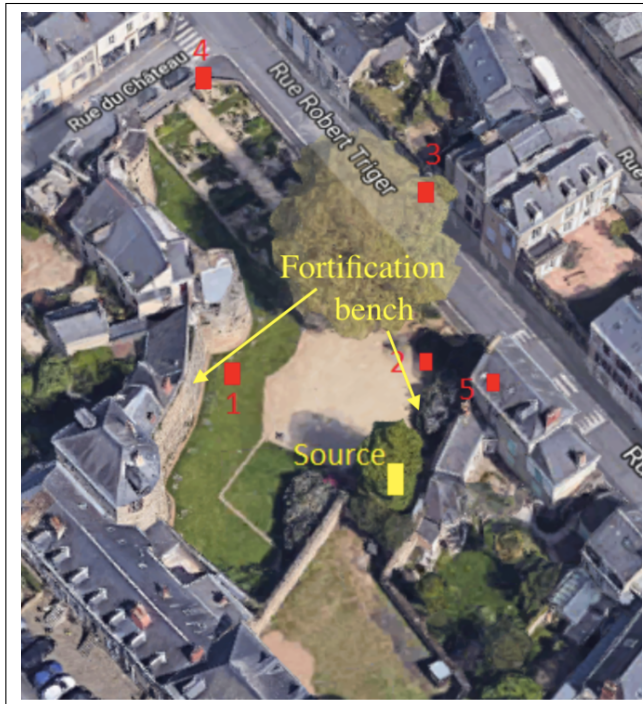


Figure 2. Guillaume the conqueror fortification. Reds points from 1 to 5 correspond to sound level measurements points.

and not too loud to disturb neighbours located at 10 m. Therefore, the sound system should be used very close from the bench.

3.4 DML panel

For the GTC fortification, it was decided to develop an original stereo Distributed Mode Layer Panel [1]. This panel vibrates under the excitation of one or several shakers. Influential parameters are :

- material,
- dimensions,
- shakers,
- position of shakers.

This study was mainly empirical with a few measurements due to lack of time.

In this project, several types of material were tested: wood, PVC and plexiglass. For similar dimensions, wood has the flattest response due to very damped modes, a warm sound rendering, but a lack of high-pitched sounds. The PVC has a bad general rendering. The plexiglass response is colored due to weakly damped modes and provides a more crystalline sound. Basses are also better emphasized. Plexiglass was chosen for the general sound rendering, the possibility of outdoor use and for the transparency for discrete integration in the overview.

A bigger plate provides more bass and a thicker plate seems to have a flatter frequency response, but is less efficient in terms of radiation. The final dimensions were



Figure 3. Robert's Doisneau House.

1300x1040x10mm³, compromise between the power required, the frequency balance, the size for implementation *in situ* (behind a bench of 2 m large), and for solidity (minimum thickness of 10 mm).

Two shakers were tested :

- a medium-high shaker (Tectonic TEAX32C30-4/B)
- a bass shaker (Visaton BS 130)

However, even with the bass shaker, when tested *in situ* with the sound designers who created the scenarios, there was a lack of bass for low frequency sounds like horse riding on the ground. A subwoofer was added to strengthen the bass range.

The position of the shakers was previously studied [3]. It is advised to place the shakers from 2/5 of a corner in length and width. This will provide a "satisfactory offset to reduce the buildup of standing waves on the panel".

Figure 4 shows a drawing of the final panel and support in order to be installed just behind a bench. Figure 5 shows the back of the installation with the transducers placement, the position of the subwoofer below the bench, and electronic equipment. Figure 6 shows the final installation with people listening sitting on the bench. The ears are less than one meter from the panels.

3.5 Sound shower

For this part, the aim was to build a directive source located below the RD's house (figure 3). Tests at the university were realized with a medium loudspeaker located at the focal point of a parabola (actually a metal bowl of 40 cm, figure 7). However, apart from a comb filter effect due to inside reflexions, the directivity of such a system is too weak. For instance, the aperture angle at -6dB is 25° around 1kHz.

Tests *in situ* provide a good sound quality for the sound scenario (mainly children voice and laughs), but the directivity was really too small. Finally, a commercial sound

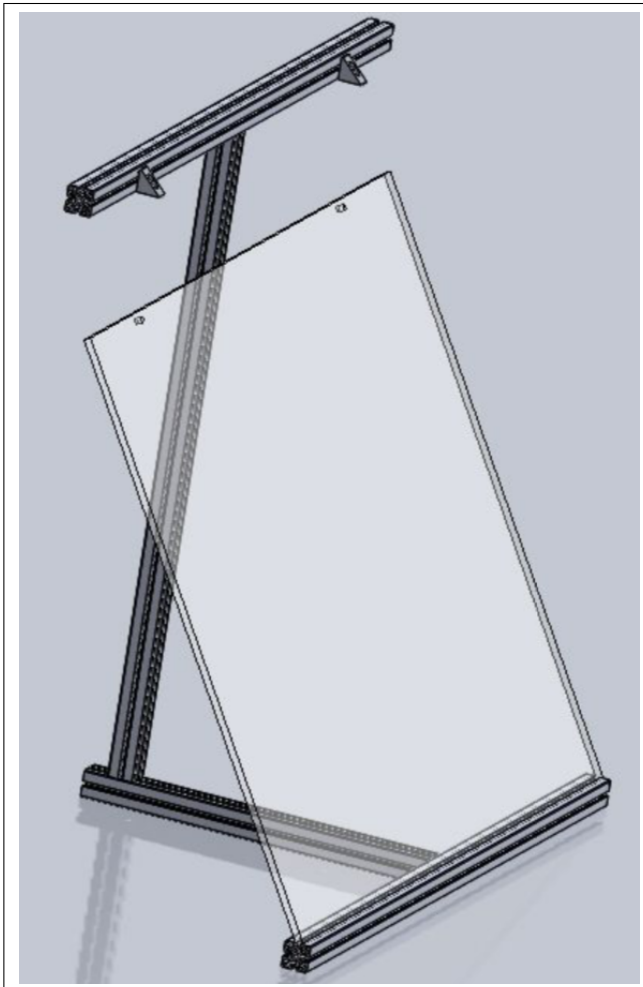


Figure 4. Drawing of the DML panel with its support. The panel is hung at the top by adjustable screw hooks.

shower (ceiling tile: capacitive Panphonics Sound Shower [4]) was finally used for the public demonstration (figure 8).

3.6 Instrumentation

The students also worked on the reading of on-board audio data, on the triggering of this reading by passage of people in front of infra-red sensors. The choice of storage and reading was carried on an SD card reader (Tsunami Super WAV Trigger from Sparkfun), an audio amplifier MAX9744 from Adafruit (2 * 20W), voluntarily triggered by push button (Big Dome Pushbutton from Sparkfun), or involuntarily triggered with a passive infrared motion sensor (PIR (motion) sensor from Adafruit). These elements have been temporarily mounted in boxes (Figure 5). The infrared triggering system could not ultimately be implemented *in situ*. Only push buttons have been used.

4. ASSESSMENT

4.1 Installation

The installation took two days in the Plantagenêt city, with the following steps and problems to solve :

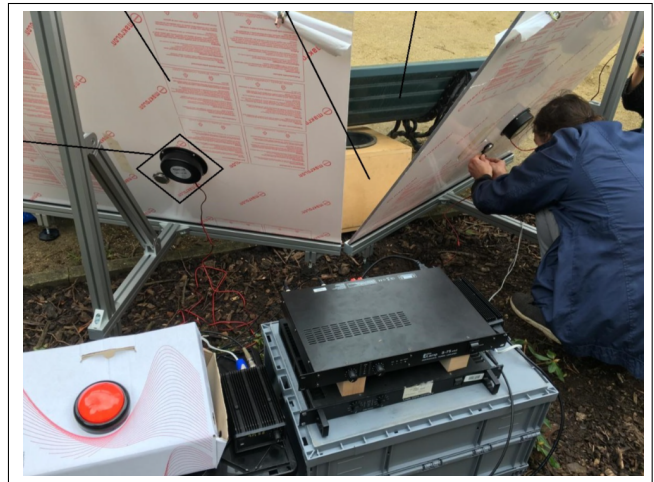


Figure 5. Picture of the panels installed behind a bench. Panels are covered here with plastic protections. Two transducers are used for shaking the panel. A subwoofer is added below the bench for low frequency.



Figure 6. Installation of panels in front of the bench to listen to battle sounds. Plastic film have not yet been removed.

- opposition to the project from a group of residents of the city.
- need administrative permits from the city and individuals to have electricity, hang objects in specific places and have access to private areas.
- transport back and forth 3 days for tests and demonstration by students and teachers of all equipment from the university to the Plantagenêt city.
- electricity connections at a few 10th of meters behind a fortification provided by the city or in the house of a private individual.
- No scaffolding provided by the city to achieve the 5m high floor of the RD's house, in a cobbled street by raining weather. Thus, a microphone boom 4m high provided by the university was used (figures 7 and 8).

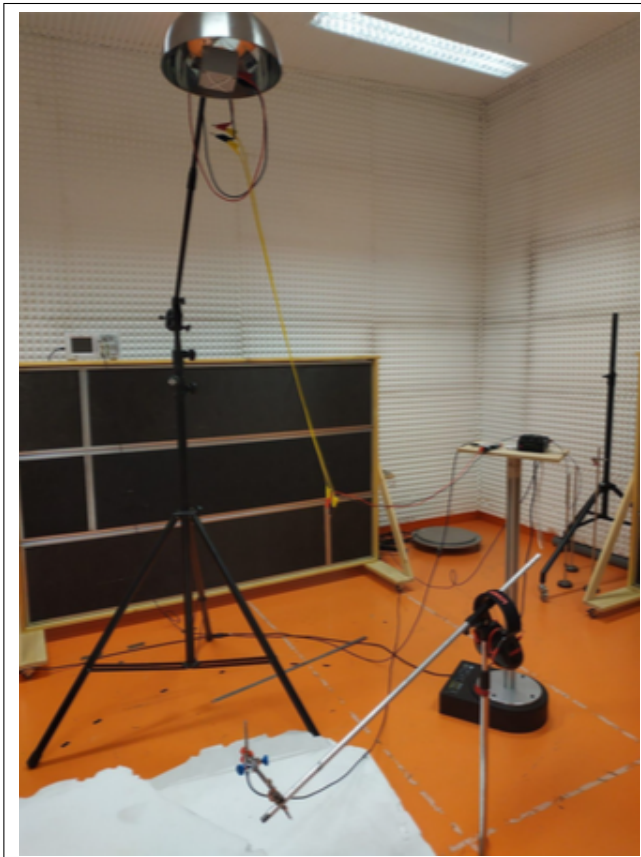


Figure 7. Experimental setup for sound shower characterization. Sound shower is made here of a closed box medium loudspeaker located at the focal point of a metal bowl.

- rain: need to stop and to cover the installation with plastic tarpaulin.
- surveillance of the equipment during the day to prevent theft.

4.2 Demonstration

Demonstration took place on march 18th. A delegation of elected officials chaired by the mayor tested the sound path. The DML setup was really appreciated in terms of sound and originality. The sound level was great enough but could not be weaker. The bass reinforcement by the subwoofer was necessary. The coloration of the sound scenario by the modal behaviour of the panels did not bother people except specialists like sound designers. The stereo effect respected the scenario creation and was appreciated also. The object panel - support was aesthetically appreciated also and could be the support for engraving ...

The commercial sound shower was also appreciated for its sound quality, enough to diffuse some sounds like children voices and laughs without bass. Its high directivity allows to focus the sound below the shower, even if, at 4 m high, the sound is guessed a few meters from the source in the street.



Figure 8. Installation of a commercial sound shower and student prototype at the end of a microphone boom 4m high.

4.3 Technological Assessment

The good rendering with the panels was possible thanks to the subwoofer. However, the initial and original idea was to make all the diffusion with the panel. Developments of the setup would be improved by a deeper study of the panel efficiency with suitable bass shakers in low frequency.

During the demonstration, even located below the RD's house with the microphone boom, the sound shower was wet due to rain and wind. Even protected from that, it would not support humidity with time. Therefore, another type of directive source should be found for this application.

The installation *in situ* (hanging, mounting, sealing, electricity ...) does not match with educational aspects of the trainings. It must be provided by the services of the city or professional companies.

4.4 Educational Assessment

The time to define a subject for the project, try to work with different types of students, choose the sites and the devices to set up, try to develop original devices, put these devices in place to make them operational, all in 6 months, did not left room for science. It is not possible to do serious modeling or characterization work under such conditions. After the fact, it would have been more reasonable to buy commercial systems directly, to characterize them in the lab and then to install them *in situ*. The scientific dimension of the project has been overlooked.

For the teaching staff, this project was very time consuming in order to manage to provide operational systems on D-Day, although not very developed. In addition, this type of project, new to us, was a tug of war between this need and the desire to do a minimum of science and meet the educational requirements of a final year engineering school project.

5. FUTURE DEVELOPMENTS

Following this project, an internship of 6 months was offered in 2019 at the Acoustics Laboratory of the University of Le Mans to improve the performance of the DML panel at low frequencies [2]. An analytical model (electro-acoustic low frequencies for the coupling transducer - panel) and classic radiation (Rayleigh integral) has been set up to study the influence of the different parameters. Experiments were carried out with a third actuator dedicated to the lowest frequencies. This work highlighted that it is possible to do without the sub-woofer and to have an effective rendering including in low-frequency domain of the proposed sound scenario.

A suite has been proposed for the 2019-2020 academic year. The list of inconvenients mentioned above led us to offer our intervention in acoustics only with the IMDEA master. Unfortunately again, the differences in educational interest in our training and project applications did not allow our students to participate. The acoustic implementation, which focused on the sound system of gardens in the Plantagenêt city, went to students of sound design. It turns out that these do not seek to understand the functioning of the systems, nor to characterize them, but are familiar with the existing systems on the market and know how to couple them with the reading, triggering, etc. systems. They are ultimately better prepared to carry out such a project. The final report has not been brought to our attention to date.

However, the 2018-2019 project raised a number of scientific and technical questions. In addition to the internship carried out in 2019, second-year student projects are currently focused on the vibrational characterization of the transducers and their coupling with the DML panel, as well as on the characterization of the Panphonics panel and on an even more directive second source (Acouspad Classic from Ultrasonic Audio Technology) based on the principle of parametric antennas.

6. CONCLUSION

This paper has presented the pedagogical approach, results, constraints, contributions and limits of a multidisciplinary student project. It consisted of developing systems of outdoor sound systems, original if possible. Acoustician students have developed a stereo pair of vibrating panels to broadcast battle sounds as well as simple directional sources. Vibrating panels were developed, reinforced by a sub-woofer for bass and was acoustically and visually appreciated during the demonstration before elected officials. The sound shower developed was not directive enough and led to use a commercial device.

This project has been very enriching for engineering students in terms of collaboration with students and teachers of other disciplines. However, it shows the limits of such a project to match the educational interests of training and the application interests of the project outside the university, in a given time frame. It is very difficult to have a scientific approach within this framework. However, this project, innovative for us, subsequently generated interest-

ing scientific activities in the form of internships and student projects carried out this time at the university.

7. THANKS

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