Sound for Electric Vehicles

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1. Introduction

In the last three years the increasing diffusion of low-emission hybrid and quiet cars has dramatically become an issue for blind pedestrians to travel safely, because these vehicles don't provide appropriate audio cues about their presence or proximity on the roads.

In 2009 Dr. Marc Maurer, president of the National Federation of the Blind[1], raised the issue of silent electric vehicles with the following words: *"We urge all automobile manufacturers to work with the blind in designing vehicle sounds to alert us to the approach, speed and direction of vehicles so that both drivers and pedestrians can safely use America's roadways".*

Since then the problem of electric vehicles (EV) and hybrid electric vehicles (HEV) has received an increasing coverage both on traditional and new media, and raised the attention of communities and car manufacturers all over the world. At the end of 2010 there are three pending legislations (Japan, U.S.A. and European Union), which have been discussed to give manufacturers the guidelines for adding an artificial sound solution to EVs and HEVs engines for safety reasons. While some manufacturers (Chevrolet, General Motors) decided to collaborate with the National Federation of the Blind, others have already entered the

[1] National Federation of the Blind's website: http://www.nfb.org/

market with a sound device dedicated for EVs and HEVs (Nissan LEAF and Toyota Prius).

The public debate is now more open and fertile than ever, with a growing community of *EV enthusiasts (or critics)*, who are collecting information in favour (or against) the application of an artificial sound solution to electric silent engines. In January 2010 the FIAMM Group, the multinational Italy-based company, asked the acoustic & sound design agency Lorelei to work on the design and development of an audio solution for EVs and HEVs.

In this article we present the current state of the project, the steps already developed and a vision of the future goals, fully aware that the debate on sounds for electric vehicles is still at the beginning and represents one of the most important challenge for the sound design and audio branding industry so far.

1.1 The client: FIAMM Group

FIAMM [2] was founded in Italy in 1942, when eng. Giulio Dolcetta pointed ELETTRA (a manufacturer of products for the navy) from the Group Pellizzari Arzignano, and turns it to FIAMM (Fabbrica Italiana Accumulatori Motocarri Montecchio). In 2000 the FIAMM Group was born, now present in 60 countries, with manufacturing facilities, sales and technical offices, and a wide network of importers and distributors. The Group production consists of starting batteries, industrial batteries and horns for automotive, marine and for first priority emergency vehicles (ambulance, police, etc.).

In recent years FIAMM made major investments in new technologies, entering the field of green economy, thanks to the production of OLED light (for automotive and general lighting), AGM batteries (for hybrid and Stop & Start engines) and the so called *salt* batteries (for electric traction, energy accumulation from renewable sources, smart grids and photovoltaic parks).

[2] FIAMM's website: http://www.fiamm.com/

1.2 The agency: Lorelei

Lorelei[3] is a sound & acoustic design agency founded in 2008 in Italy that is active in the fields of sonic interaction design and sonic branding. In particular Lorelei works for the sonification of public and private spaces, and for product sound design. In the last years the agency developed solutions for bathtubs, beds, electric vehicles and temporary structures for national and international firms. The team is composed by professionals in the fields of sound design, music composition, interaction design, software development and brand communication. Some members of Lorelei are also active in disseminating the culture of sound and audio design, writing for the blog sounDesign[4] and taking part in national and international conferences, festivals, public talks and lectures.

2. Sound for Electric and Hybrid Cars

As initially stated by the National Federation of the Blind, EVs and HEVs are very dangerous because of the absence of sound emitted by the electric engine. In particular, these silent cars can seriously harm the following group of pedestrians: visually impaired people, children, bicyclists and, last but not least, animals.

In September 2009 the National Highway Traffic Safety Administration[5] published the technical report *Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles* (R. Hanna, 2009), a study on the incidence rates of pedestrian and bicyclist accidents, conducted comparing HEVs and internal combustion engine (ICE) vehicles under similar circumstances. The result of the study underlined that HEVs were involved in a higher number of crashes than ICEs when in specific vehicles low-speed maneuvres (turning, stopping, backing up or moving in a parking space).

[3] Lorelei's website: http://www.loreleiproject.com/

[4] SounDesign blog: http://www.soundesign.info/

[5] National Highway Traffic Safety Administration's website: http://www.nhtsa.gov/

In a recent interview Deborah Kent Stein, chairwoman of the National Federation of the Blind's Committee on Automobile and Pedestrian Safety/Quiet Cars[6], declared that this report "demonstrated that the silent operation of hybrid vehicles is an issue for all pedestrians, not just the blind"[7]. Other useful information come from the noise levels measurements of both combustion and electric engines. In fact an electric vehicle is silent at a speed between 0 and 20 mph, but when exceeding 20 mph the noise level converges, due to the dominance of tires and wind noise. The issue of *silent deadly cars* can therefore be described under two conditions:

- vehicles travelling with a speed between 0 and 20 mph;
- vehicles making specific manoeuvres (parking, reversing, turning, etc.).

In the last years many solutions were studied and proposed: GPS devices for blind people, radar systems (already introduced in cars to detect obstacles), flashing lights and sound devices. The adoption of sound seems to be the most effective solution for many reasons. First of all sound is efficient according to our perception, because a person (or an animal) is able to detect a sonic input faster than a visual one. Audio cues can also be designed to convey information about the state of the vehicle not only to pedestrians, but also to the driver. In addition a sound-based system is cost-effective, if compared to other proposed technologies.

Anyway the public debate recently showed a big concern about the adoption of a sound solution, because it can cause an increase of sonic pollution in our roads, in opposition to the trend of the last ten years of reducing sound emissions in conventional combustion engine vehicles. On these assumptions the issue of quiet electric cars opens a new scenario, in which the use of sound represents a huge branding opportunity

[6] National Federation of the Blind's Committee on Automobile and Pedestrian Safety/Quiet Cars' website: http://quietcars.nfb.org/

[7] National Federation of the Blind teams with Chevrolet and GM to incorporate a safe sound alert for electric vehicles and hybrids, november 2009: http://www.nfb.org/nfb/NewsBot.asp?MODE=VIEW&ID=518

for cars manufacturers, which could customise their products. Indeed sound can be a branded solution for both external warning sounds (for the safety of pedestrians) and internal feedback sounds (for information to the driver).

At last the dangerously absence of sound is an issue related not only to HEVs and EVs, but more generally to the next generation of ICEs, industrial vehicles and other special vehicles (motorcycles, public transport, etc.). In this novel and open scenario, Lorelei worked for the FIAMM Group with two main goals: to design audio content for providing external sonic cues for pedestrians and finally to design the prototype of a device to control and diffuse these contents on a electric vehicle.

2.1 Methodology

Lorelei developed a specific process of work for the issue of electric cars, which consisted of three main stages: a preliminary study to define the concept of a novel sonic solution, a phase of sound design for the creation of the sounds assets, and a final stage in which the solution is applied using the software simulators developed by the agency and the hardware devices prototyped together with the customer.

A first part of this process was divided in the following activities: context analysis, concept analysis, brand analysis, technology analysis, sonic content analysis, sonic sketching and software prototyping. Three different teams were involved in these activities: a group of researchers to study the theoretical issues and define the guidelines for the proposed solution; a group of sound designers and engineers to design and develop the sound assets; a group of software engineers to develop the software simulation.

A second part of the process is still in progress and consists of the following steps: hardware prototyping, testing sessions in a real environment, dissemination and communication campaign. In the following paragraphs a brief description of the first group of activities of this process is given.

Context analysis
A study was conducted about the public context that lead to the development of the deadly silent cars issue and its state of the art. This step involved analysis and monitoring of: research and data reported by stakeholders (National Federation of the Blind, National Highway Traffic Safety Administration, car manufacturers), articles and discussions on conventional media (magazines, newspapers), web-based discussions (forums, blogs, communities, social media), political debate (guidelines, laws, political claims), available or foreseen technological solutions, public tests and surveys with associations and consumers on different proposed sound solutions.

Concept analysis
It is a preliminary analysis to identify a concept for the design of the sound contents. This step consisted of a study of the history of the electric car revolution, its social, philosophical and cultural meaning. A deep analysis was made on its representation in arts, cinema, literature and in advertising and communication campaigns created by all the most important car manufacturers.

Brand analysis
The sonic branding opportunities define a future scenario in the field of sound for electric vehicles. At this stage, our brand analysis involved the study of an abstract concept which could be described properly with the questions: "What are electric cars for us? What is their identity? How should they sound like then?". The brand analysis lead us to a concept which can be summarised with the following claim: "State of the art Technology allied with Nature".

Technology analysis
A series of hardware/software work sessions were conducted to test two different technologies provided by FIAMM: the Multi Sound Horn device (see **Figure 1**) and a well defined category of external speakers. These sessions aimed to understand what sonic features could be developed in the next steps of the activities.

Sonic content analysis
The team analysed the features of warning and attention sounds, with tools and studies based on psychology of perception, psychoacoustics and acoustics.

Sonic sketching
The first sonic content was designed working on the core elements identified by the previous steps: context, concept, brand, technology and sonic analysis.

Software prototyping
Lorelei's software team developed a dedicated virtual simulator based on Max [8] (see **Figure 2**), with the aim to create the sound contents and test their dynamic evolution according to a number of real-time data coming from the car (speed and acceleration).

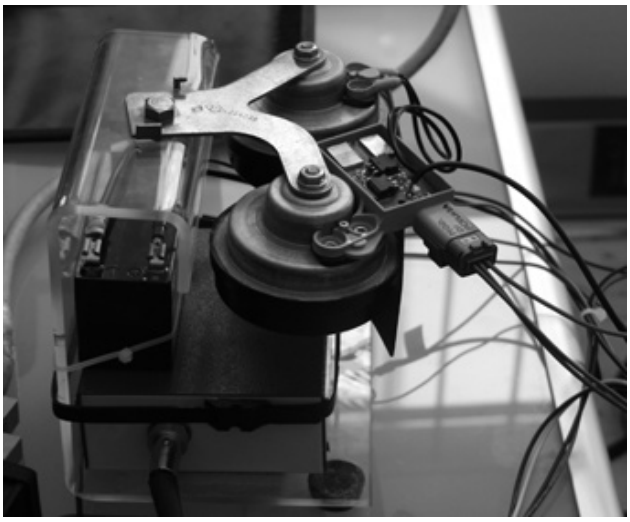

Figure 1. Multi Sound Horn (MSH) device provided by the FIAMM Group.

[8] Max is a visual programming language for music and multimedia developed and maintained by San Francisco-based software company Cycling '74: http://cycling74.com/products/maxmspjitter/

2.2 The solution

The software simulator developed in the final stages of the process was connected to the hardware systems provided by the customer, in order to evaluate different sound solutions and improve the features of the sound contents created by the sound design team.

The proposed solutions were based on the following assumptions:

- the sound has to provide a warning for all the categories of pedestrians and also for animals and cyclists;
- it must respect and preserve the current soundscape;
- it has a strong and high potential for brand identity and brand awareness;
- a potential extension to silent conventional and special vehicles has to be considered.

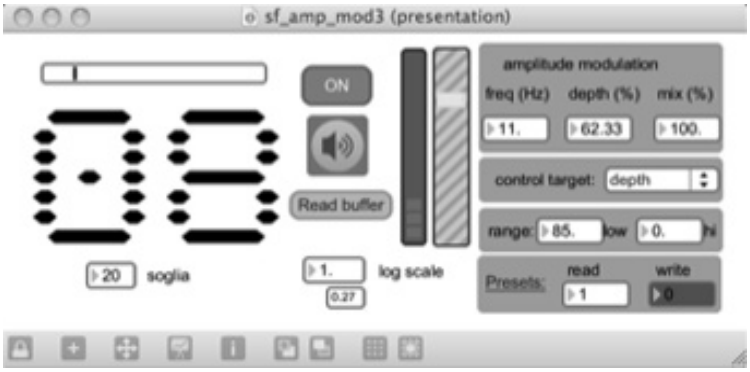

Figure 2. An example of patch in Max developed for the virtual simulator.

At the current stage of the project the proposed solutions are three (see table 1). A first solution is modelled on FIAMM's MSH device: the dynamics of the sound content is based on the perceptive recognition of rhythmic patterns. For this solution we proposed the following claim: *EV is natural, not artificial*.

A second solution is modelled on the external loudspeakers provided by FIAMM: the dynamics of the sound is still based on the recognition and evolution of rhythmic patterns. For this case the proposed claim is: *EVs are technologies allied with Nature & Mankind*.

A third solution is still modelled on external loudspeakers, but in this case the vehicle dynamics combines the adoption of pitch shift and rhythmic patterns. This solution suggests a higher potential for sound branding and it is based on the claim: *EVs are state-of-the-art technologies allied with Nature & Mankind*.

model	device	concept
1	MSH	EV is natural, not artificial
2	external loudspeaker	EVs are technologies allied with Nature & Mankind
3	external loudspeaker	EVs are state-of-the-art technologies allied with Nature & Mankind

Table 1. Proposed solutions: the virtual simulation software is connected to the hardware systems in order to design different models of sounds.

3. Conclusions

In this article we presented the current state of a work aimed to design the sound for electric vehicles. We presented a future oriented solution, with no fake engine sound, which proposes sound contents consistent with the novel concept of the electric car.

Three different sonic solutions were designed, based on the assumptions that sounds must warn pedestrians without degrading the soundscape and can be modelled according to product audio branding principles. Future work will address the prototyping of a dedicated hardware to conduct testing sessions in environments with real users, in order to

improve and verifiy the adopted sound solutions. At the end Lorelei and FIAMM believe that sound for EVs can be a great opportunity to create a new soundscape for our lives in the future.

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