# RoadMusic :

## Music For Your Ride From Your Ride

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## ABSTRACT
RoadMusic is an artistic project, which generates music for in-car listening, from information gathered while driving. We will describe in detail how the system works, and briefly define our intentions in initiating this project. We will demonstrate how, through the musical format that is generated from the data, there is a possible subliminal perception of the situation. We will suggest ways in which this can be regulated to respond to criteria of security and usefulness. We will describe future research using RoadMusic in electric vehicles.

## Keywords
Subliminal perception, In-vehicle audio, Sonification, Music

## 1. INTRODUCTION
### 1.1 Objective
The ultimate objective of RoadMusic is to use processes of sonifcation to create generative music tightly coupled to the dynamics of driving an alternative to recorded or broadcast in-car music, which is both musically satisfying and informative of the environment. The music produced in this manner has applications in creative solutions to the silence of electric cars, and might provide a suitable support for less urgent audio alerts. The current, prototype version is being presented as a creative musical composition system in the context of new media art and electronic music.[1]

### 1.2 Background
We are investigating the artistic possibilities offered by real-time sonification[2] of data, in this context we are particularly interested by what might be considered as extensions to human phenomenology made possible through the use of mobile or embarked computers. If sonification is rapidly gaining importance in the technical and scientific domains it is far from being ignored by sound artists and musicians [14]. While dependent on recent technology in its present form, we can find the origins of artistic sonification in theory going back as far as Pythagoras and his music of the spheres. It is practically impossible to perceive the audio environment or soundscape[3] through which a car is travelling and to all intents and purposes there is no, naturally occurring, audio environment inside a modern car -this holds particularly true for electric cars. There is a strong culture of listening to music while driving or being driven, in fact according to a recent ICM survey for omnifone[4]it is where the most musical listening is done.

RoadMusic generates music in real-time from data concerning movements of the car and the visual environment through which it is travelling. As such it is mediation of the environment and of the car's interaction with that environment. If this mediated information is perceived as essentially abstract and partly preconscious or subliminal music; the fact remains that the music does convey its information to the driver's (and passenger's) ears.

Sonification is a highly pertinent topic for commercial manufacturers of electric cars. However, present efforts tend to be focused on externally sonifying the car to indicate its approach and presence to pedestrians. RoadMusic sonifies the environment and driving dynamics for the benefit of those inside the car, ostensibly to raise awareness of driving conditions, and for the passengers, for whom with the same sound, we hope to create a pleasant musical experience that could possibly replace traditional music. In this way, the system overcomes the potentially dangerous, effects of loud music isolating the driver from important events in the surrounding environment, while creating an agreeable in-car sonic environment.

Research exists concerning the effect that listening to music and other audio cognitive tasks, has on drivers' concentration I. D. Brown in a 1965 article [2] suggested that listening

*Creative Research Into Sound Art Practice
[1]See the project website: http://roadmusic.fr for details.
[2]'Sonification is the use of non-speech audio to convey information data to sound'. G.-Kramer:1999kx
[3]Term coined by Canadien composer and theorist Murray Schafer in 1969 [12]
[4]Omnifone/ICM: February 2010: sample 1000 UK adults percentages : car- 71; living room -66; PC -35; ipod -33; mobile -15)

to music was beneficial -since it reduced the frequency with which the accelerator and brake pedals where used. More recent research underlines the influence of the genre and overall amplitude of the music but is less conclusive 'These findings support evidence for music as a source of in-vehicle distraction, which can have both positive and negative effects on driving performance' [5]. We can conclude from this research, that listening to audio tasks distracts driving concentration slightly, while there might be a relaxing influence related to listening to music, which is generally considered to be positive. We propose that permanent preconscious monitoring of environment through musical listening, might have an overall, beneficial effect on the users awareness of that environment compared to normal musical listening -a hypothetical parallel could be made by comparing the awareness of a pedestrian (unconsciously) hearing his or her naturally-occurring audio environment to that of a pedestrian listening to music unrelated to that environment through headphones.

As far as we know, current research into sound that mediates the vehicle environment itself, is limited to the reproduction of familiar sound sensations; by amplifying the sound of the combustion engine in certain almost silent modern vehicles the (e.g.Peugeot RCZ ) or by varying recorded sound, in an analogy to engine noise in electric cars (e.g. Renault FRENDZY [3]). Most studies concerning in-vehicle audio-display concentrate on alert or alarm sounds and the comprehensibility of their signification [4] [9]. Other research into musical sonification, such as that conducted by Ralph Jung and Tim Schwartz [11] attempts to insert precise semantic information into the musical composition through the use of earcons[5]. Our approach is rather different, the original intent being to inform in an abstractly musical, rather than a semantic way and the audio material being treated on a concrete rather than symbolic level.

## 2. DESCRIPTION OF ROADMUSIC

### 2.1 The system *AutoSync*

The program runs on a dedicated mini PC that is plugged into the auxiliary input of the car's audio system. Information about the car-drive is captured by accelerometers that stream data concerning the x,y and z movements of the car and a camera, which is used to analyse the visual landscape. The program is written in Pure Data[6] and runs on a Linux (Mint) operating system.

### 2.2 How it works

#### *2.2.1 Sonification Strategies*

Several different techniques of sonification are employed simultaneously and superposed as multiple 'gestalt' wholes, creating a complex, polyphonic end result:

- Audification
- Stream based Parameter Mapping
- Feature extraction/Event mapping

[5] *an icon for your ears* that lets you hear a notification as opposed to reading it The term was coined by Sumikawa in an article called 'Guidelines for the integration of audio cues into computer user interfaces'. [15]

[6] Pure Data, is an open source programming environnement developed by Miller Puckett. [10]

**Figure 1: AutoSync for RoadMusic - PC, accelerometers and camera.**

#### *2.2.2 Audio Production*

No recorded audio is used in the system (excepting a recorded voice, used as an audio display in response to user commands). Audio synthesis at the lowest level is based on audification of the stream of incoming data using wavetable synthesis (as opposed to algorithmically created waveforms such as sine waves or white-noise). Wavetables are read by oscillators and combined to create different modules or 'instruments'.

#### *2.2.3 Data Mapping*

On a higher-level data streams vary instrument parameters in real-time. Feature Extraction/Event mapping is used: to trigger change within an instrument; to switch instruments on or off and to calculate average values - creating subsequent control streams. Thresholds extracted from the average value streams are used to orchestrate the ensemble.

### 2.3 The Data is the Waveform

G-force data, measured by accelerometers, is continuously written into lookup tables. This means that while pitch (the melody) is defined algorithmically within the program; the timbre of the sounds varies continuously in relation to the road surface, vibrations of the motor or other larger movements of the car. Several tables are allocated to data from each axis (x y and z), amplitude values are stored in tables of different sizes, ranging from 36 to several thousand samples. Wavetable oscillators (which scan the table at the audio rate of 44100 samples per sec) mediate the route on different timescales dependant on the size of the allocated table. This translates concretely as difference in timbre and defines the speed at which the timbre varies: its reactivity. This audification works on a microscopic scale and the auditor is not necessarily consciously aware of changes -it does however modify the listening experience: The sounds are perceived as 'live', as such they might be compared to those produced by acoustic instruments. They resist better to prolonged listening than algorithmically synthesized or recorded waveforms.

### 2.4 Synthesis Modules/ Instruments

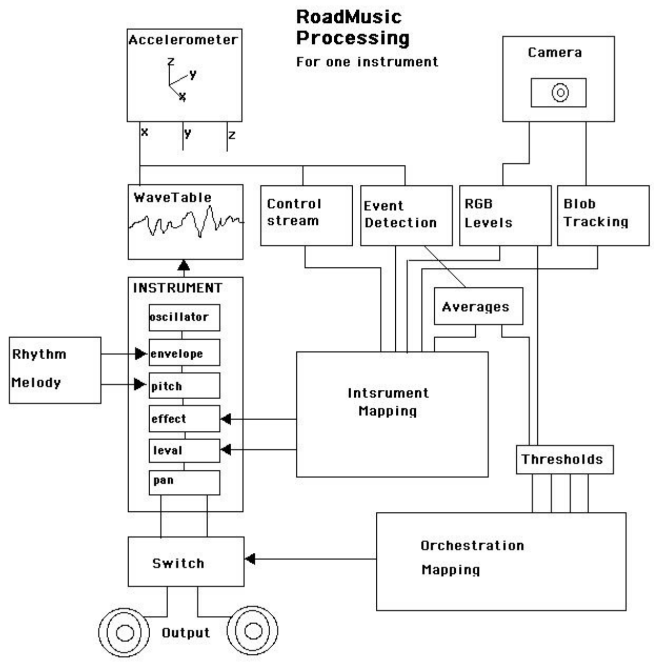


**Figure 2: Data and Audio Processing in RoadMusic.**

- The audio processing part of the program is organized as a series of modules; 'instruments' that implement these wavetable oscillators in different ways to produce different sounds. We employ a variety of digital audio processing techniques (additive, subtractive, granular synthesis etc.) thus reinforcing the separate timbral identities of the different instruments.
- Further effects such as: filtering, reverberation/delay, pitch shifting, and distortion are applied to these audio signals and varied in real-time by data streams.
- Overall amplitude and position in the stereo field (pan), is controlled in real time by data streams. Instruments are 'played' melodically, rhythmically, as continuous drones, or as events.
- Melodic instruments share a common musical scale defined algorithmically within the program and rhythmical instruments share a common 'metronome'.

## 2.5 Data Analysis

### 2.5.1 Movement

Data from the accelerometers is interpreted in different ways and on different timescales.

- Each data stream is rescaled so that it can be used as a continuous controller for the parameters described in paragraphs above. For example the varying force of acceleration and deceleration, or g-force as the car goes round bends or over bumps, can be mapped to amplitude, pitch, tone, delay speed etc.
- Events are detected within these same streams by measuring difference against time, so it is possible to discern a bump, a bend, an acceleration etc. These events are used to trigger sounds directly; to introduce or remove notes from melodies; or to switch signal processes (instruments) on or off.
- Detected events are quantified using moving frame averages. These averages generate a new, slower stream that is a more general indication of the type of road or driving style -a measure of 'bumpiness', 'bendiness', 'stops and starts' etc. These can be mapped to parameters of instruments, causing slower variations that mediate the drive on a macroscopic scale.
- Threshold values are extracted from the moving frame averages, producing a new set of events, used to orchestrate the ensemble, switching different instruments on or off according to the frequency of events and therefore the characteristics of the drive (e.g. straight, some curves, winding).
- No event: if no event is detected over a period of several seconds (which generally corresponds to the car's stopping or giving way) a 'change' event is generated, which is used to reset instrument parameters such as melody and rhythm.

### 2.5.2 Visual Field

A camera captures an image of the road ahead. This image is analysed in different ways:

- Blob-tracking based on frame difference is used to distinguish large moving objects, most often cars in the opposite lane. A detected object is represented by it's moving x,y and z coordinates, which, as with the accelerometers can be mapped to any parameters of any sound. In practice, they are employed to create the impression that the movement of an instrument in the music follows that of an object outside the car by using psycho-acoustic cues (panning, amplitude and doppler shift).
- Average, RGB (red, green, blue) levels of the whole scene are calculated and used as a data streams, typically to vary harmonic elements in an instrument.
- An event is extracted when there is a change in the dominant colour of the landscape.

## 2.6 Data Mapping-Composition

A versatile mapping system allows the composer to route any chosen data stream or event to any parameter of any instrument. The composer can do this in studio conditions by using recorded datasets and video image to playback a journey. In practice this is a long process of listening and adjusting so that the mapping sounds 'right' in the vehicle -this judgment, as in most musical composing is essentially subjective. However some 'figurative' correlations are made so that events or parameters correspond to appropriate sounds (a bump for instance produces a percussive bass drum sound which echoes rhythmically in the music). The following are some of the ways in which the data is mapped:

- Real-time data streams are mapped to instrument parameters, typically; pan; pitch-shift; rhythm or counter-rhythm shift.

- Events are used to; switch on and off instruments; add or remove notes in a melody; trigger correlated sounds; switch effects on or off.
- Moving frame average streams are mapped to; amplitude; reverb; frequency-filters.
- The 'No event' or change event is used to; choose a new musical scale and tonality (this choice is determined by light level and dominant colour values); determine an overall metronome value (determined by preceding averages); stochastically generate new melodies from the common scale.

# 3. ARTISTIC MOTIVATIONS

Without getting into the philosophy behind our artistic motivations in too much depth, We should mention that we are particularly interested by the artistic possibilities offered by 'real-time' , 'real place' mediation. This is in opposition to art, which is fixed in time, as is the case with traditional fine arts, or which implies a specific temporal context, a special occasion as is the case with the performing arts or cinema. We consider that the advent of mobile computers offers the possibility to create extensions to personal phenomenology, as opposed to exhibiting the unique reflection of another individual's (the artist's) phenomenology.

# 4. EVALUATION

The objectives of this research are to see if creative music processes can create innovative solutions that reconcile driver awareness with a pleasant driving experience. In the development, the musical compositional process is paramount, and is the current focus of development of the system. We are running workshops with practicing composers to create a range of music for the system, and with that output, will test the system in user studies in an electric car at Newcastle University's Social Inclusion through the Digital Economy project. The compositional process is initially intuitive and like any other artwork, results are difficult to assess objectively. The user studies now being organized (see section future research below) will consist of controlled experiments which take into account participants, subjective opinion and their objective behavior.

Preliminary studies to date have been through demonstrations of RoadMusic at cultural manifestations such as new-media or contemporary music festivals. During these events participants are driven for approximately 20 minutes. The results below relate to video interviews[7] conducted using semi structured interviewing techniques with 10 participants - 9 passengers who were interviewed immediately after their experience and 1 driver who was interviewed after driving the car for 3 evenings, (roughly 12 circuits).

- In general participants declared having enjoyed their experience. Most described having initially sought to understand the correlation between events and sounds and then having settled down to listen.

[7]Conducted by Dr Noemie Behr during the festival 'Mois du Multi' Quebec in February 2010. The origional recordings (in French) are available on the RoadMusic website [13]

- General impressions tended to describe the sound as being between environmental and musical: participants used expressions such as; englobing; like a film sound track; a dialogue between the interior and the exterior; abstract; coherent as a general ambiance.
- Some participants considered that there should be more direct correlation between sounds and events, however opinion diverged on this point. The driver suggested that it was unnecessary to seek correlation since we do not seek correlation when we listen to a symphony orchestra; we simply accept a code. He also said that his musical experience changed as he repeated the demonstrations and that he learnt that driving down a specific street would produce such or such a type of musical experience another street, another.
- All the participants declared that they would like to have the system in their own car, but most suggested (spontaneously) that it would be preferable to be able to choose when to listen to it.

The shortcomings of this method of evaluation are that:

- The public in the type of events covered do not represent a cross section of the population: they tend to be specialised or at least interested in experimental music.
- Some explications where given during the demonstration, therefore the participants where possibly influenced in their opinion or comprehension.
- Participants experience RoadMusic as an event and not as a permanent or long-term feature of their driving environment.

# 5. CONCLUSIONS

## 5.1 The De Facto Subliminal Content

As described above the waveforms read by oscillators that initiate the chains of synthesis in RM are in fact tables filled with continually renewed data from the sensors. Most of the time this fact is not consciously perceived, that is to say: the more obvious harmonic structure of the sound and its variations -for instance in pitch as it plays a melody- are determined at a 'higher level' in the program. It is only when there is a abrupt change in conditions, in the roads surface for example, that there is a notable variation in sound attributes. However the rest of the time the fact that there are slight imperceptible variations in timbre, modifies our overall perception: although we are listening to (obviously) synthetic sound, it maintains our attention compared to the same synthesis generated from fixed waveforms, which can rapidly become monotonous. These microscopic variations also inform the listener subliminally, of the evolving situation.

The driver is not necessarily aware of what action is causing what musical variation, to give an example: a given change may be due to fluctuating statistics gathered over the last 10km, which in turn will continue to have effect over the next 10km. Another change might correspond to the accumulated influence of navigating a curve in the road and a change in dominant colour. Over the course of time, as the compositional process has developed, we have learnt to balance immediate effect (a sound parameter mapped directly to a sensor) against those changes which are influenced on a macroscopic scale. The contrary -direct mapping alone- although sought after in a first experience, can rapidly become uninteresting for the listener. With experience it is possible for a driver to recognize and possibly interpret, complex configurations and combinations, but this tends to happen through the global recognition of a previous similar sound experience as opposed to the immediate, conscious tracking of a given signal.

The mapping of RoadMusic incorporates more than 100 routings, some of which have an extremely subtle influence on the musical result, creating complex 'layered identities'[8] that are almost impossible to disentangle in terms of cause and effect. However these differences are recognizable in the quality and 'feel' of the music rather than as interpretation of quantifiable information. This is in keeping with musical 'attention' in general, which while being undeniably precise and particularly sensitive to slight variation, takes place for the most part on a preconscious level or at least a non-symbolic level of consciousness: arguably sensations and emotions generated by sound are difficult to express or explain in words. Inversely semantic information encoded as sound does not create what is generally considered as a musical result [6]. We propose that because RM mediates data of the environment, beyond it's being a musical experience it also fills the role of soundscape. This in turn suggests that whether we are listening or not, we hear everything that is happening albeit unconsciously: "you can close your eyes but you can't close your ears" [1].

## 5.2 Composer/Programmer responsibility

If as we intend RoadMusic is to be made available to a wider audience, programming the system, even in the context of entertainment, implies a certain level of responsibility. It is important to take into account potentially dangerous situations and possible negative influence on driving style -born from the desire to test the system. At one point during the development of the system, hard braking triggered a loud and harsh sound. If in terms of cognitive correlation, of source bonding, this might seem coherent, in practice it is an unwelcome interference. When we have to brake hard it generally means that there is a critical or semi critical situation that requires our undivided attention and, in this context (after the driver has started to react), loud sounds do not help (as they can if incorporated as alerts before the driver has reacted). The programmer|composer has a choice: it is equally possible to create a silence in the case of sudden braking as to create a loud noise. Similarly, it is not a given that an increasing value in data equates an increasing value in the music. For instance an excessive number of accelerations could be interpreted in such a way as to slow the musical tempo, making the music more soothing rather than the opposite; the effect that we might expect intuitively.

## 5.3 'Useful' Cues

Future versions of RM could be organised to include more obviously useful information. We are accustomed to sonification as hyper-presence in the form of alarms or alerts but in some cases this might be overkill. We take in most of the useful information in our audio environment without it being projected to the forefront of our consciousness and often our actual perception might have more to do with absence than with event. For instance the sound of a refrigerator of which we are subliminally conscious is noticeable only at the moment when it stops or starts. In our natural environment we might be alerted to the approach of danger by the croaking of startled crows, or we might be alerted because songbirds have ceased to sing [7]. Changes or ruptures in rhythm and melody are important audio cues in music, and are also influential in inducing behaviour or reaction. An example of a useful cue in RoadMusic might be to remove a powerful rhythmical element if the car's proximity sensors detect that the car is too close an obstacle, and to reinstate the rhythm when the danger is past. This sonification by elimination is not necessarily in contradiction with the use of audio alarms or alerts - it might be envisaged that certain frequency bands be reserved for these sounds.

# 6. FUTURE RESEARCH: USER TESTING IN ELECTRIC CARS

Up until now Road music has been presented in an artistic context. The University of Newcastle's Transport Operations Research Group (TORG) directed by Phil Blythe and Newcastle University's 'Culture Lab' directed By Atau Tanaka are collaborating to organize user testing of RoadMusic.

TORG are currently taking part in a UK government funded scheme to develop and trial electric cars in the Newcastle area. There are 44 vehicles involved in the scheme, which are made available to the general public on preview trial. TORG also possess their own electric vehicle (Peugeot iON) specifically for testing purposes.

The hard data on the cars are derived from the CAN bus of the vehicle and transmitted to a secure database through the use of wirelessly enabled data loggers within the car. This is overlaid with GPS and time data derived from an additional logging unit in the vehicle. The loggers have been designed to take some external analogue and digital inputs. These inputs include the GPS and time-stamp data as well as a number of analogue inputs from current-clamps which are attached to various electrical systems of the vehicle to measure current flow and battery drain.

In the first instance we will install the RoadMusic system in the University's vehicle, which is currently being used to record data with two regular drivers who are accustomed to the car. We will therefore be able to compare data collected during tests with RoadMusic with previous datasets recorded with the same drivers. This should provide us with objective information concerning the influence of RoadMusic on driving style. The advantage of this method is that we can test the driver's behavior over a relatively long period (several weeks) thereby eliminating the 'novelty' element and objectivizing the possible temptation to test the limits of the system. A second round of tests, dependent on obtaining a specific budget, will involve a group of between 5 and 10 participants, exterior to the University and representing a cross-section of the population. The tests will take place over a minimum of 6 weeks. Weeks 1 and 2 will be used to habituate the driver to the car and to record datasets of driving without music. Weeks 3 and 4 will be used to record datasets with music of the driver's choice. Weeks 5 and 6 will be used to record datasets with RoadMusic.

Evaluation: Three methods will be employed:

1. 1 As described above datasets without music, with music of the participant's choice and with RoadMusic, will be compared in order to evaluate the influence of RoadMusic on driving behavior.

2. 2 A double questionnaire will be addressed to each participant individually before and after the RoadMusic driving experience. The questionnaire preceding the experience will explain the basic principals of the system and interrogate the participant's expectations. The questionnaire following the experience will reiterate the same or similar adapted questions; the difference between these responses should provide an adequate indication of the participant's actual experience. The questions will be formulated to cover the following topics:
   - Does/did the participant imagine/find that the music will be/was enjoyable
   - Can/does the music express the situation.
   - Does/did participant consider that the music will be/was distracting or focalising.

3. 3 A focus group will be organised where all the participants anonymously discuss the following question:
   - Did the participant feel the necessity or desire to switch off RoadMusic in given circumstances and if so which circumstances? Is this different to normal in-car listening to radio or chosen recorded music?
   - Did the participant feel the desire to test the responses of the car+RoadMusic by exaggerating his or her driving?
   - Did participant feel that they where listening to information, listening to music or hearing an environment, or none of these?
   - Did the participant consider that the music adapted to their drive?
   - Did the participant consider that their driving was enhanced or distracted by the music?
   - Did the participant 'feel' or 'understand' the audio output of RoadMusic?
   - Did the participant feel that the sound/music was produced: by a program, by themselves, by the car, by the road or none of these?
   - When driving with passengers, did the driver feel that they where responsible for the quality(s) of the music? If so did this influence their driving and how?
   - Did passengers have the same appreciation of the music as drivers?
   - Would the participant like to have the system permanently installed in their vehicle?

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