Acoustic simulation in realistic 3D virtual scenes

Thierry Cathala[1], Pierre Naz[2], Patrick Gozard[3]

[1] *Oktal Synthetic Environment, 2 rue de Boudeville, 31100 Toulouse, France, Email: cathala@oktal.fr*
[2] *ISL, 5 rue du Général Cassagnou, 68300 Saint Louis, France, Email: naz@isl.tm.fr*
[3] *DGA/DCE/ETBS, Rocade Est – Echangeur de Guerry, 18021 Bourges, France, Email: patrick.gozard@dga.defense.gouv.fr*

Introduction

The simulation workshop CHORALE (**CH**amp de bataille **O**ptronique **R**adar **A**coustique simu**LE**) is used by government services and industrial companies for multisensor simulations in realistic 3D virtual scenes (visible, infrared, EM and acoustic simulations). The need is, for example, the simulation of the multi sensor detection of moving vehicles in 3D scenes. This article describes the acoustic model in CHORALE and the validation tests based on the results of international acoustic detection experiment NATO/TG25.

CHORALE features

To create an acoustic simulation using CHORALE, the user needs to prepare a simulation scenario. The scenario is described by a 3D scene, a set of sound sources (associated to moving vehicles), a set of acoustic sensors and a characterization of the atmosphere (air temperature, atmospheric pressure, humidity, wind velocity and direction according to the altitude). The 3D scene is described by a set of polygons. Each polygon is characterized by its acoustic resistivity or its complex impedance.

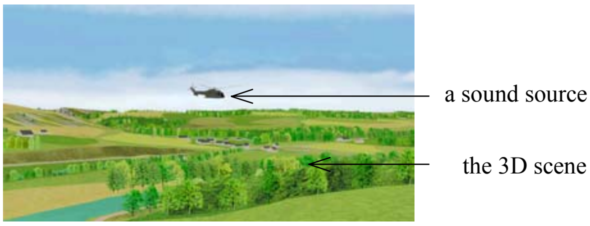


Figure 1: Example of 3D scene

Sound sources are characterized by their spectra and directivities. Acoustic sensors are defined by their positions, their bandwidths and their directivities.

The purpose of the acoustic simulation is to calculate the spectral incoming acoustic pressure on acoustic sensors. The results can be post processed to create a .wav file. CHORALE is based on a ray tracer. This ray tracer possesses original capabilities: computation time is nearly independent on the scene complexity especially the number of polygons, databases are enhanced by precise physical data, special mechanisms of antialiasing have been developed that enable to consider very accurate details. The ray tracer takes into account the wave geometrical divergence, the atmospherical absorption, the attenuation of sound due to trees and forests, the wind and Doppler effects, the sound diffraction by edges (hill, wall, ...) and the sound wave refraction due to air temperature gradients.

Modelling tools

CHORALE is composed of a set of tools that enables the user to create the 3D scene, to enhance this 3D scene with physical data, to create a simulation scenario, to calculate and visualise "images".

The first step is the preparation of the simulation. Using the modelling tools of CHORALE, the user can prepare all the necessary data. **AGETIM** is a terrain modeller, based on the Geo Concept GIS. **GAIA** is a physical modeller, and is used to associate acoustic parameters such as resistivity or acoustic impedance to the polygons created by AGETIM. **ATC** is a tool dedicated to the definition of atmospheric profiles.

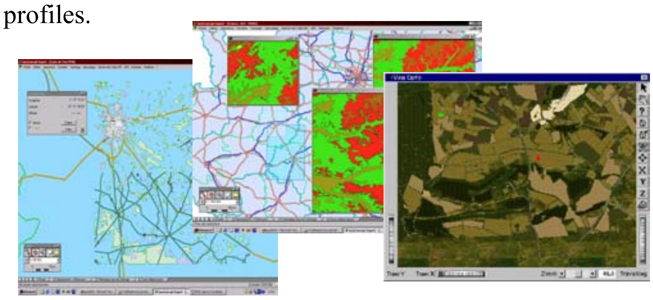


Figure 2: *AGETIM* : Terrain modeler

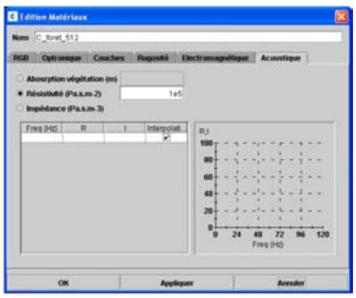


Figure 3: *GAIA* **:** Tool for the edition of the physical properties

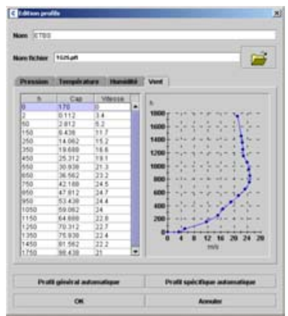


Figure 4: *ATC* **:** Tool for the edition of atmospheric data

Simulation tools

SPECRAY is the ray tracer of CHORALE. According to the data created with the modelling tools, SPECRAY allows the creation of a scenario and the computation of the incoming pressure for all the acoustic sensors in the 3D scene. "Acoustic" beams are cast from each sound source, in all directions, through an "acoustic system" (cf. **Figure 5**). composed of a set of pixels. The beams are propagated into the 3D scene, interact with polygons, are reflected or diffracted, and, for some of them, are received by a sensor.

Antialiasing

Antialiasing is a ray tracing method that allows the focalization of acoustic beams on the complex parts of the 3D scene. The beams are split recursively in 4 sub-beams.

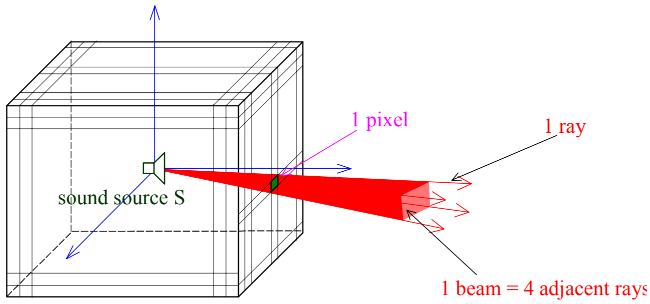


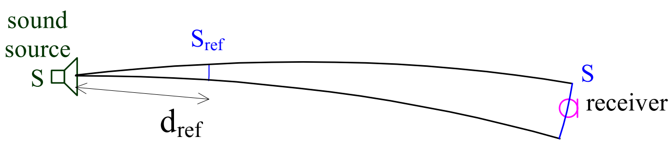
Figure 5: Acoustic system for the ray tracer

The antialiasing mechanism is adaptative: it allows a pixel splitting proportional to the 3D scene complexity.

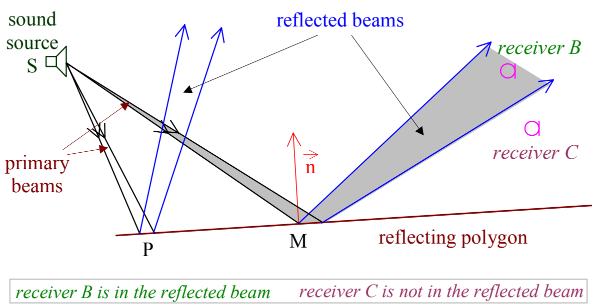
The acoustic software takes into account:

⇨ the atmospheric transmission, according to the ISO 9613-2 norm,

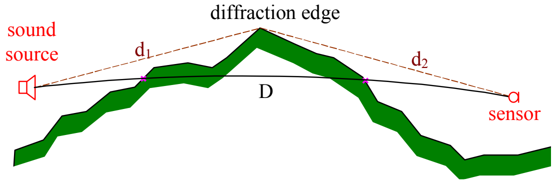
⇨ the geometrical divergence, proportional to $\sqrt{\frac{S_{ref}}{S}}$.



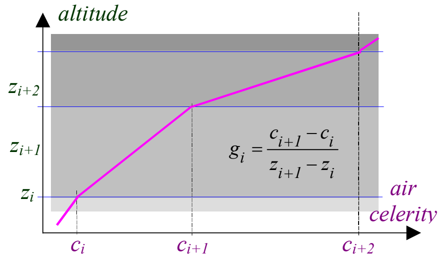
⇨ the reflection on materials, characterized by the acoustic impedance Z_S or acoustic resistivity σ. Primary ray tubes are emitted by the sound source. If the ray tube intersects the geometry of the 3D scene, then a reflected ray tube is built according to the local normal vector $\vec{n}$ in the reflection point M. This mechanism is implemented recursively and one ray tube can generate a tree of reflected ray tubes. At each "stage" of the reflection, SPECRAY checks if each receiver belongs to the reflected ray tube.



⇨ the diffraction on edges (the attenuation is calculated as a function of the Fresnel number $N = 2 \cdot \frac{d_1 + d_2 - D}{\lambda}$)



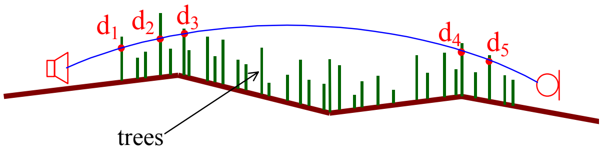
⇨ the refraction of acoustic waves due to vertical gradients of air temperature. Atmosphere is modeled by horizontal layers characterized by a constant gradient of sound celerity. This gradient is calculated according to the profiles of air pressure, air temperature, wind speed and wind direction profiles.



⇨ the natural and non natural diffuse sources (wind noise, rain noise, …),

⇨ the transmission through the vegetation (forest, trees, …), function of the frequency f and the thickness d of foliage :

$$A_{tree}(f) = \frac{f^{1/3} \cdot d}{100} \quad \text{with } d = \sum d_i$$



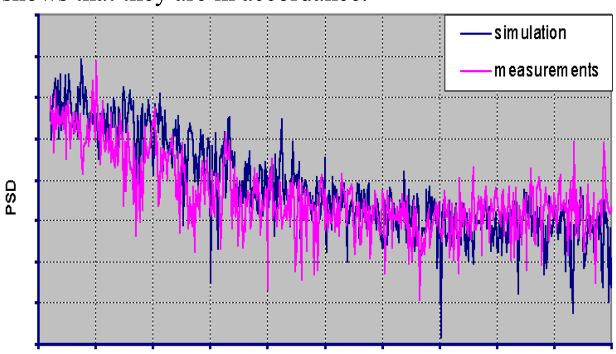
⇨ the speed and orientation of wind,

⇨ the Doppler shift of moving objects,

⇨ the sensor and sound source directivity.

Validation of the acoustic simulation

Unitary tests were performed to validate each functionality of the acoustic model. Recently, a global validation test was performed. The comparison between the measured acoustic signal on a TG25 trial and the calculated acoustic signal shows that they are in accordance.



References

[1] Unattended acoustic sensor simulation of TG25 trials using CHORALE workshop. Gozard, Le Goff, Naz, Cathala, Latger, Dupuy, SPIE, 2004

[2] Acoustic simulation in realistic 3D virtual scenes. Gozard, Le Goff, Naz, Cathala, Latger, SPIE, 2003