Automatic 3D virtual scenes modeling for multi sensors simulation

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ABSTRACT

SEDRIS that stands for Synthetic Environment Data Representation and Interchange Specification is a DoD/DMSO initiative in order to federate and make interoperable 3D mocks up in the frame of virtual reality and simulation. This paper shows an original application of SEDRIS concept for research physical multi sensors simulation, when SEDRIS is more classically known for training simulation. CHORALE (simulated Optronic Acoustic Radar battlefield) is used by the French DGA/DCE (Directorate for Test and Evaluation of the French Ministry of Defense) to perform multi-sensors simulations. CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and generate the physical signal received by a sensor, typically an IR sensor. In the scope of this CHORALE workshop, French DGA has decided to introduce a SEDRIS based new 3D terrain modeling tool that enables to create automatically 3D databases, directly usable by the physical sensor simulation CHORALE renderers. This AGETIM tool turns geographical source data (including GIS facilities) into meshed geometry enhanced with the sensor physical extensions, fitted to the ray tracing rendering of CHORALE, both for the infrared, electromagnetic and acoustic spectrum. The basic idea is to enhance directly the 2D source level with the physical data, rather than enhancing the 3D meshed level, which is more efficient (rapid database generation) and more reliable (can be generated many times, changing some parameters only). The paper concludes with the last current evolution of AGETIM in the scope mission rehearsal for urban war using sensors. This evolution includes indoor modeling for automatic generation of inner parts of buildings.

Keywords: SEDRIS, Simulation, ray tracing, infrared, electromagnetism, acoustics, GIS, terrain modeling

1. SEDRIS, CHORALE AND SE-AGETIM

1.1. What is a SE and SEDRIS

Environmental data is an integral part of many of today's information technology applications. The available environmental data amount grow exponentially. Consequently, the tool requirements for manipulation of environmental data grow.

A **Synthetic Environment** (**SE**) is the aggregation of all the required information in order to model a virtual 3D environment and then to make use of it. A SE is made of geometrical information (for instance the terrain shape), geographical information (for instance the feature nature & identity), material information (for instance the thermal conductivity), radiative information characterizing the behaviour in front of radiation (for instance the Bidirectional Reflection Distribution Function or the self emission power of the atmosphere), structural information (for instance the way a wall is built), tactical information (for instance the potential to be destructed), semantic information (for instance the engine rate of a vehicule), operational information (for instance the population density) … Typically, the SE may contain a worldwide representation of earth including its whole atmosphere. As a comparison, a SE is equivalent, for a natural landscape, to a CAD file for a manufactured object.

The representation and sharing of SE, in other words, **the SE interoperability**, is now playing a key role in the interoperation of heterogeneous systems and applications that use such data. The motivation is the consistency requirement of most of modeling and the cost reduction.

This need was recognized in the mid-1980's, when the ability to network large numbers of heterogeneous simulation systems became a practical reality. Research and work in this area continued while a better and more complete understanding of the complex issues associated with describing and sharing of environmental data for a wide variety of (simulation) applications was formed. SEDRIS was conceived in order to tackle these issues in a uniform and unified way. The range of end-applications includes representation of SE for such applications as analysis, visualization, simulation, planning, modeling, etc. This takes into account the meteorological and oceanographic communities, the simulation sector (both military and commercial), the GIS (or more broadly, the environmental information systems) community, the military operational community (i.e. C4I), as well as others who need to share or communicate environmental data. According to this idea, the SEDRIS (Synthetic Environment Data Representation Interchange Standard) has been conducted as an open project with the objective of solving this challenge. SEDRIS is fundamentally about both the representation of environmental data, and the interchange of environmental data sets.
To achieve the first, SEDRIS offers a data representation model, augmented with its environmental data coding specification and spatial reference model, so that one can articulate one's environmental data clearly, while also using the same representation model to understand others' data unambiguously. Therefore, the data representation aspect of SEDRIS is about capturing and communicating meaning and semantics.
For the second part, practice indicates that it is not enough to be able to clearly represent or describe the data; we must also be able to share such data with others in an efficient manner. So the second aspect of SEDRIS is about interchange of data that can be described using the data representation model. For the interchange part, the SEDRIS API, its format and all the associated tools and utilities play the primary role, while being semantically coupled to the data representation model.

1.2. What is CHORALE

CHORALE is a multi-sensor battlefield modeling **workbench** mainly used by French DGA, German BWB and by South Korea MoD, in order to achieve the synthesis of 3D scene observed by a sensor, this in two steps:

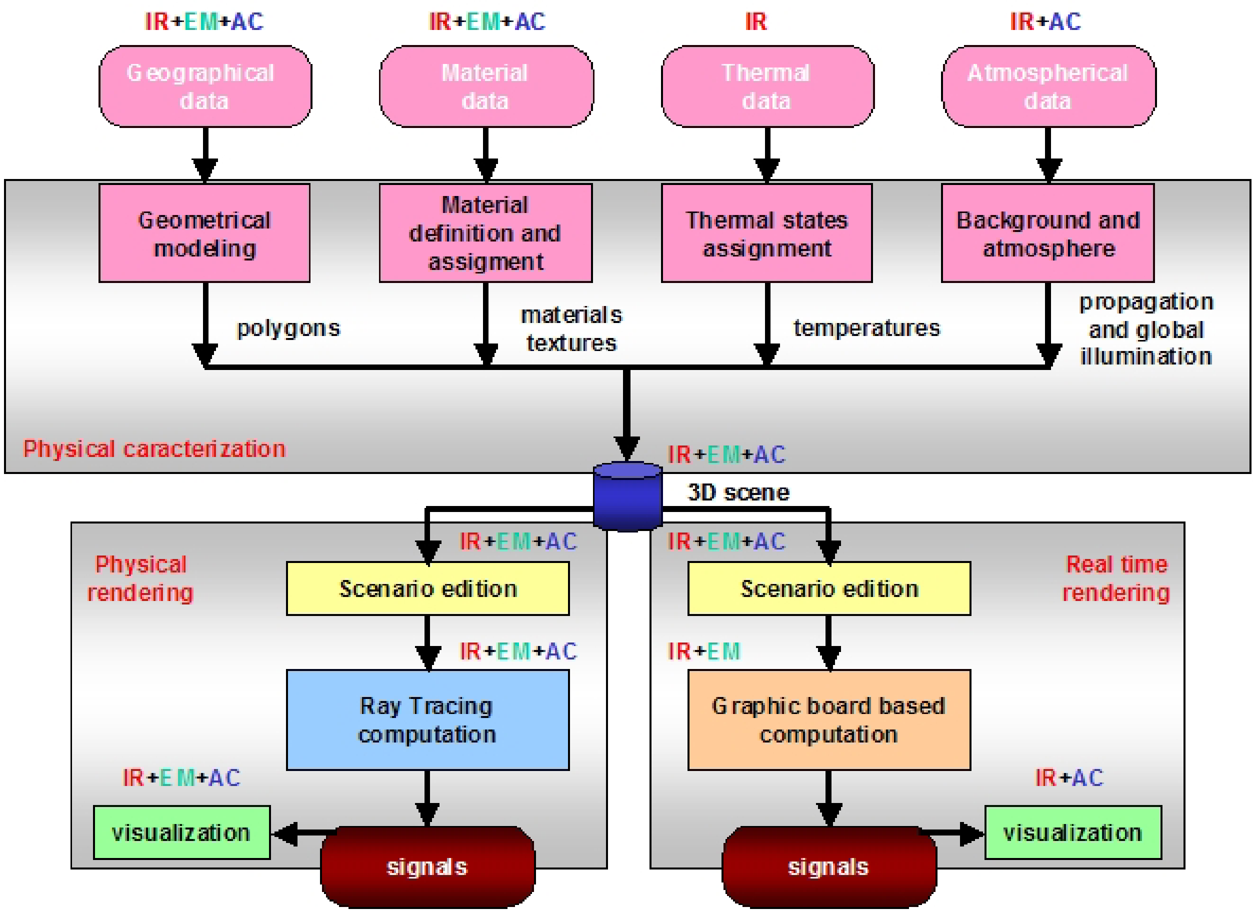
- The 3D scene physical behavior characterization
- The Computation of the physical signal received by a sensor

CHORALE is entirely based on the SE-Workbench from OKTAL-SE and realize the multi-spectral unification of optronic, electromagnetic and acoustics, using a common kernel & physical extensions affectation both aimed at a unique 3D scene and a common technology. CHORALE is a winning initiative for sharing R&D efforts and federating a user group community that intends to exchange experience and knowledge.

The first CHORALE development was in 1994 and has been strongly boosted by the French SCALP missile program and the qualification of the IR tracking system. At the beginning, CHORALE was focused on the IR domain. In 2003, an acoustic version already described in previous SPIE conferences, has been developed. In 2001, an electromagnetic version of the CHORALE workshop was initiated, with the help of ONERA French research center, mainly focused on millimetric waves and wide scenes, typically for SAR applications.
The CHORALE 3D scenes are very precise and realist, using textures in order to accurately define the material geo mapping, as illustrated in the following CHORALE synthetic image:

The CHORALE validity domain control is based on both a theoretical validation (development of physical models, general modeling and simulation knowledge, elementary tests and validity assessment) and a validation by experiments (SCALP/EG missile [FR], Storm Shadow missile [UK], AASM missile [FR]).

The CHORALE architecture can be declined in 3 functional architectures for infrared (**IR**), electromagnetic (**EM**) and acoustic (**AC**) domains sharing the same following organization :



1.3. What is SE-AGETIM

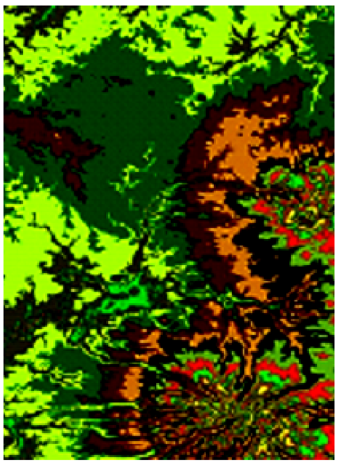
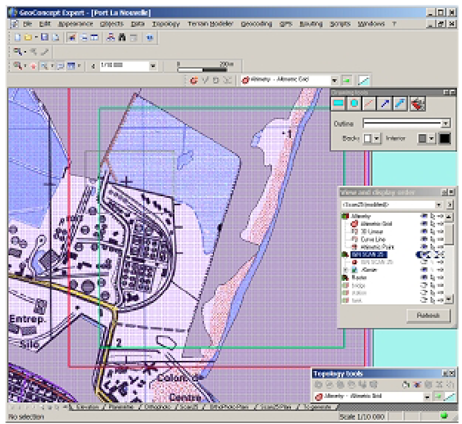
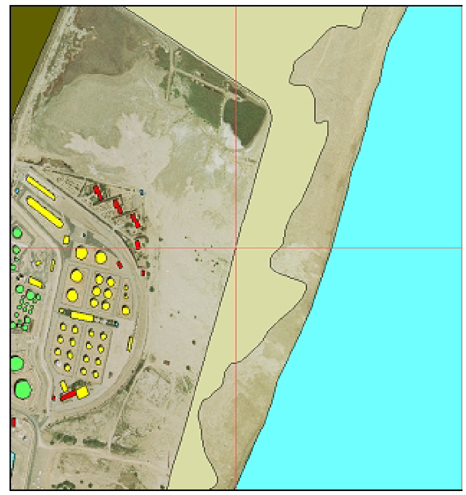
SE-AGETIM is the CHORALE tool dedicated to terrain modeling. The SE-AGETIM input data are **source data** made of altimetry, planimetry and picture (satellite, airborne, ground).
The SE-AGETIM tool includes the French GÉOCONCEPT **Geographic Information System** API.

SE-AGETIM accepts the following combination of projection and geodesic systems :

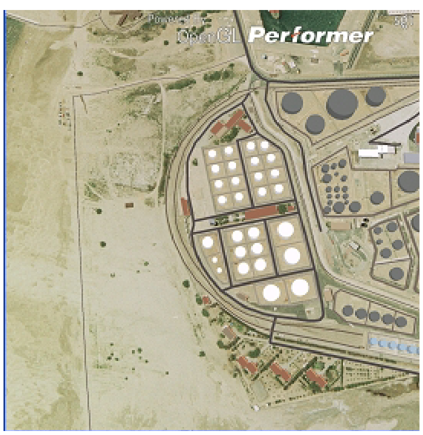
Coordinates system	North UTM ED50	North UTM WGS84	Conical Lambert
projection	cylindrical	cylindrical	conical
geodesic system	ED50	WGS84	NTF

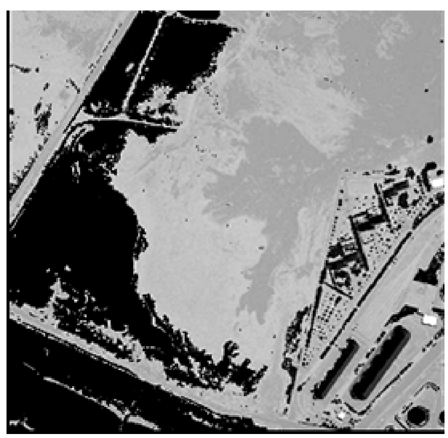
The **planimetry** is made of the outlines of fields, lakes, forests, buildings and others, of the axis of roads, rivers and others, of the anchor points of objects. This set of punctuals, linears and areals can be represented as 3D geometries.
The **altimetry** can be regular grids, with various resolutions, or set of points (irregular grids) or height curves. Those data are handled in the GIS and fully managed by SE-AGETIM.
Those data can be real data of the terrain or fictive data needed for simulation on a set of generic data. They can be topographic accounts, air photos, geo-referenced or not, planimetric and altimetric data, digitalised or created manually using plans or photos.

Example of altimetry, planimetry, photography data:

and then the generated 3D scene visualized in visible, IR/band II and EM/SAR domains:






1.4. SEDRIS and SE-AGETIM

OKTAL-SE has developed import and export SEDRIS format functions in SE-AGETIM. Moreover, in the frame of validation and configuration management of source data, using the SEDRIS API, and some complementary SEDRIS tools (aimed at visualizing, manipulating and controlling source data), analyzing tools have been realized that enables to:

- Visualize
- Manipulate
- Control
- Qualify
- Validate

SEDRIS data are enhanced with metadata for data qualification.

A first class of metadata concerns the use constraints and the security level:

Access	
access_constraints	*String*
uconstraints	*String*
security	*Security_Info*

Security_Info	
system	*String*
classification	*String*
handling	*String*

A other class concerns the reference of the metadata and the data origin:

Citation	
title	*String*
edition	*String*
originators	*String*
series_name	*String*
issue_id	*String*
other	*String*

Data_Quality	
process	*String*
process_date_of_creation	*Date*
fictional	*Boolean*
property_accuracy	*String*
logical_consistency	*String*
completeness	*String*
abs_horiz_pos_accuracy	*String*
rel_horiz_pos_accuracy	*String*
abs_vert_pos_accuracy	*String*
rel_vert_pos_accuracy	*String*
Description	
abstract	*String*
purpose	*String*
other	*String*

OKTAL-SE has developed within SE-AGETIM a specialised bundle of functions enabling to control and analyse the data quality both lexically and semantically, and, in some cases, to correct the source data, using the SEDRIS environment.

1.5. SEDRIS and CHORALE

CHORALE is manipulating an impressive set of data quite necessary in the frame of physical simulation of IR, EM and AC domains. OKTAL-SE has developed a SEDRIS like data structure both at source level (before 3D meshing) and at meshed level, including enhancement with physical data.
Concerning SEDRIS, it is planned to provide a true SEDRIS CHORALE representation. The first step is the definition of a CHORALE TCRS (Terrain Content Requirements Specification). The second step is the documentation of the CHORALE mapping in SEDRIS i.e. of the mapping of internal CHORALE mapping in the CHORALE TCRS in order to develop the full interface CHORALE/SEDRIS.

2. TERRAIN GENERATION

2.1. SE-AGETIM-V2 general principles

SE-AGETIM is a ten years old product that has recently been completely reshaped for mainly two reasons:

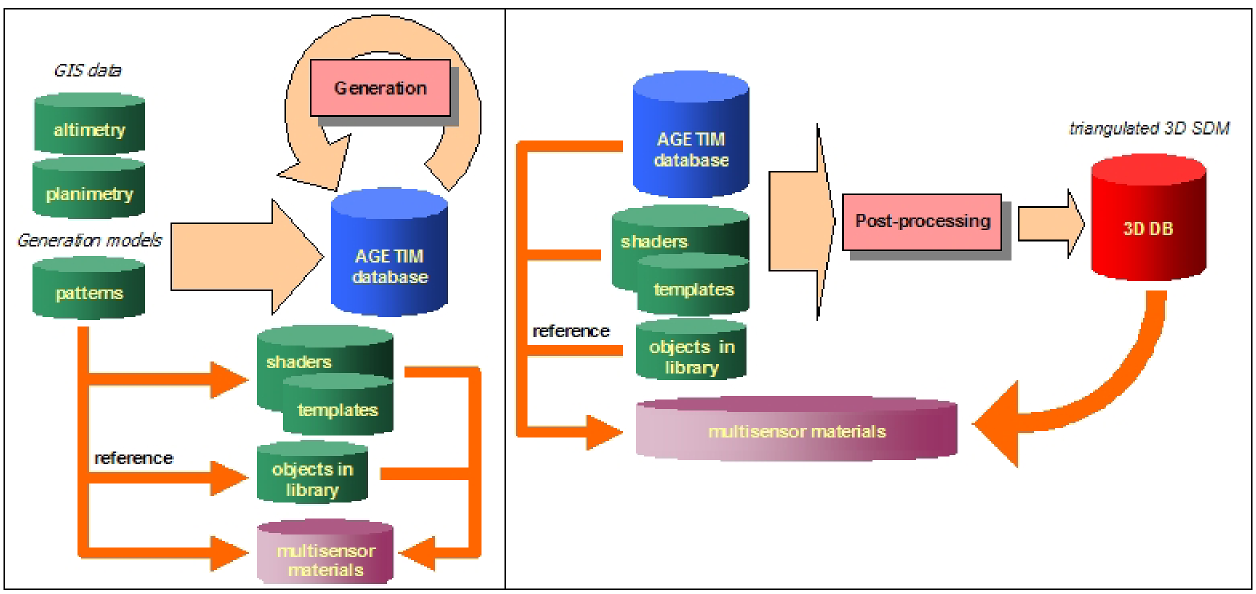
- First, in order to tackle to generation of very large terrains (hundreds km x hundreds km)
- Secondly, to fit to new rendering approaches (procedural generation of terrains),

always paying attention to the fundamental requirement for physical representation i.e. the ability to introduce in the same run all the IR, EM and AC attributes to the automatically generated SE.
To illustrate the first reason, let us precise that the new version of this CHORALE terrain generation tool, called SE-AGETIM V2, has been used to create a full re-generable 3D SE for French MoD, corresponding to one half of France country, in the frame of a helicopter application, both with “man in the loop” application (for embedded sensors assessment) and for vulnerability and counter measures studies.

According to the second reason, the first targeted application is the CHORALE/SE-RAY-IR and CHORALE/SE-RAY-EM ray tracing kernel for IR and EM, in order to take advantage of procedural generation processes directly implemented in the rendering pass of the ray tracing, for instance consisting in generating automatically micro vegetation like grass or more generally clutter information typically for EM application. The second targeted application is similar, but in the frame of new generation rendering 3D real time engines (like video games middleware), typically CHORALE/SE-FAST-IR V3, the new version of CHORALE infrared rendering, based on OpenGL pixel shaders.
The main conceptual difference between the previous release of SE-AGETIM and the V2 new reshaped product is that previous version simply produced a set of triangles with associated materials, whereas new V2 product generates an organized ***database*** that combines both source level and meshed data. With the new V2 product, every required attribute from the source level might be used at any step of the generation process. The user application might also access directly the SE-AGETIM database, or require a post processing operation, performed by a ***useskill***, which translates the database into an application understandable structure. For instance for standard viewers, a useskill will convert the database into a set of triangles with associated materials, as in previous modeller version.
Basically, the architecture of the V2 requires two distinct steps:

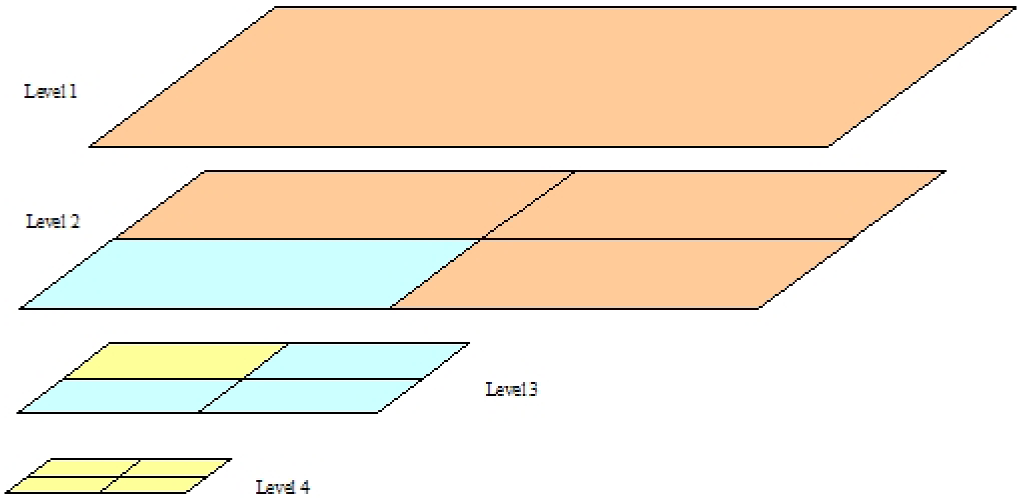
- The source data generation that is collected into the AGETIM database, which evolves during the whole process
- The post processing using specific useskills that turn the database into common application standard files, for instance the "STATICLOD" useskill that generates static level of details from the generated database, and exports 3D triangles set with their associated materials.

These two steps are illustrated here after:

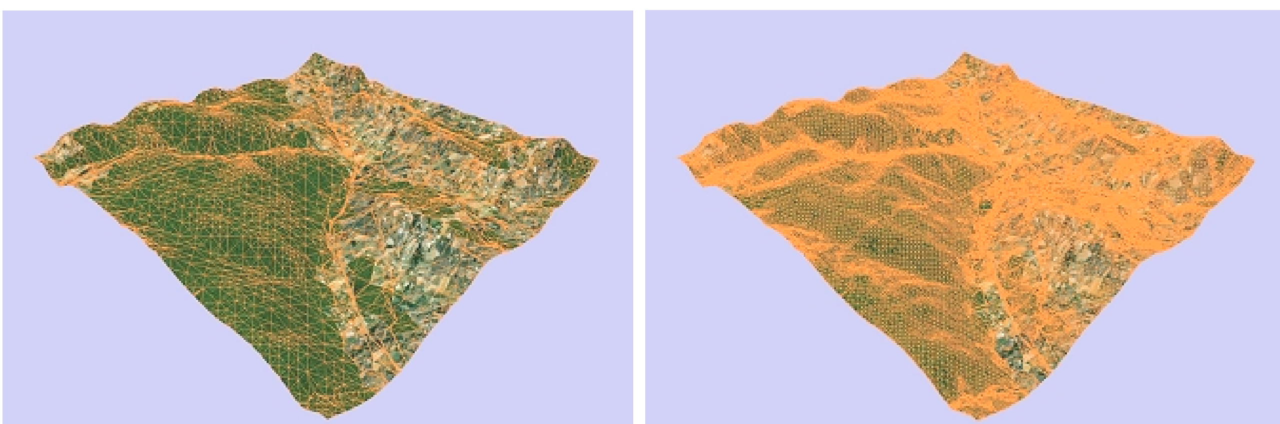


2.2. Continuous LOD for terrain generation

SE-AGETIM previous version was based on an irregular meshing (Delaunay algorithm). SE-AGETIM V2, that aims at generating continuous Level Of Detail of the whole terrain (including altimetry, features and textures) has been enhanced with a quadtree hierarchical decomposition of the terrain as illustrated here:



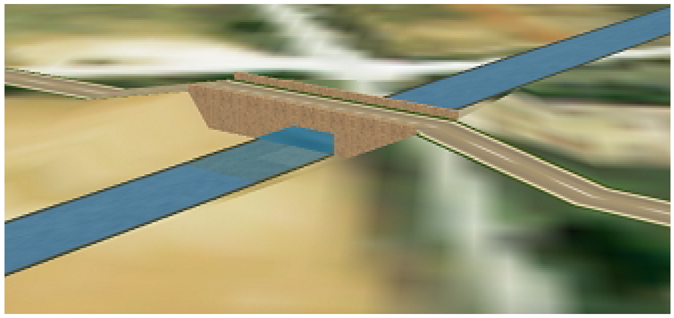
This enables to simplify the terrain and 3D feature representation for instance function of the observation range, typically being more accurate in the front plan than in the second plan:



There is a lot of other advantages typically for the feature conforming to the terrain or for texture morphing, as explained in the next paragraphs.

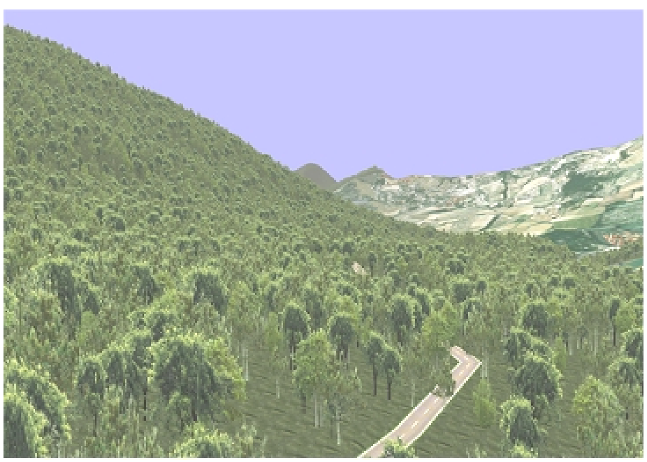
2.3. Patterns for feature generation

SE-AGETIM V2 introduces two new concepts called a ***buildskill*** and a ***pattern***.
A buildskill is a data specific generator. Each data is handled by one buildskill which is "intelligent" and defines the data behaviour. The buildskill also controls the data coherency.
A pattern defines a data generation model. It specifies both the material and the geometrical characterisation of the generated data. It gathers some parameters required by a given buildskill to achieve the full generation process. The pattern may also collect additional information that could be used by a useskill.
As for now, there are several distinct patterns that can be derived to define any wanted user pattern. Some of these patterns are dedicated to generically handling punctual, linear and areal features. The other are dedicated to the terrain, and more global generation parameters.
The figure below illustrates the effect of an "integrated punctual" pattern (the bridge) and "intersection pattern" (the road and river crossing):



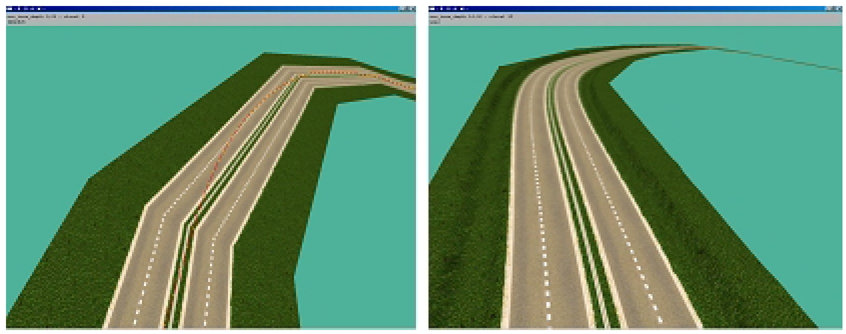
2.4. Shaders for advanced representation

The CHORALE user also has access to much more advanced generation models through the use of SE-AGETIM ***shaders***.
A shader defines an advanced generation parameterisation used by a useskill to perform advanced tasks, such as forest sowing or road profiling. The shader mechanism operates a set of basic shader operations, that are elementary treatments, for different representations, that are level of details.
A lot of pre defined shaders are available that enable for instance to flatten the inside of an areal feature (a lake, an ocean portion …), extrude a 2D profile along an axis (a road template …), or perform advanced generation of data such as growing houses or forests.
The shader mechanism could be assimilated to a minimal script language that allow the useskills to perform some operations. The associated XML based format allows level specific generation, in order to have different data representation for different level of details.
The pictures here after illustrates the application of a coverage shader for forests:



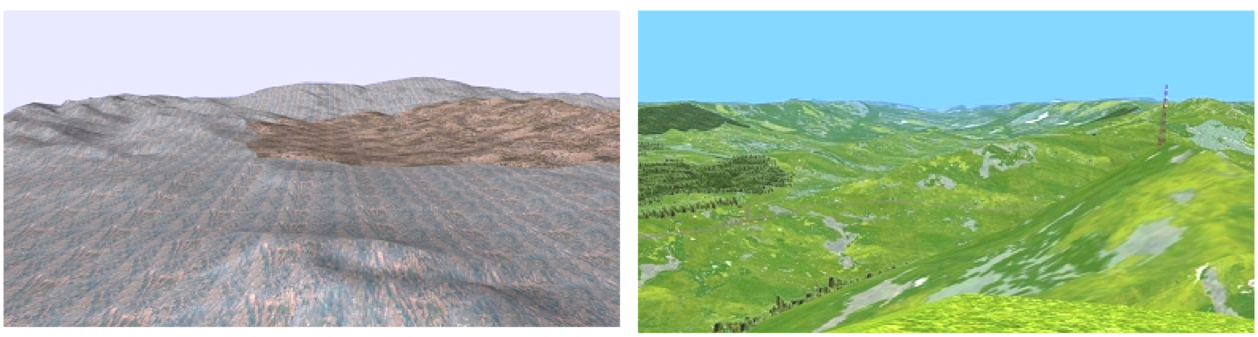
2.5. Texture morphing

One key advantage of the SE-AGETIM V2 quadtree hierarchical generation of terrain and features is the capacity to twist and morph the texture using a close combination of meshing and texture mapping deformation, as illustrated in the figure below:



2.6. Multi texturing

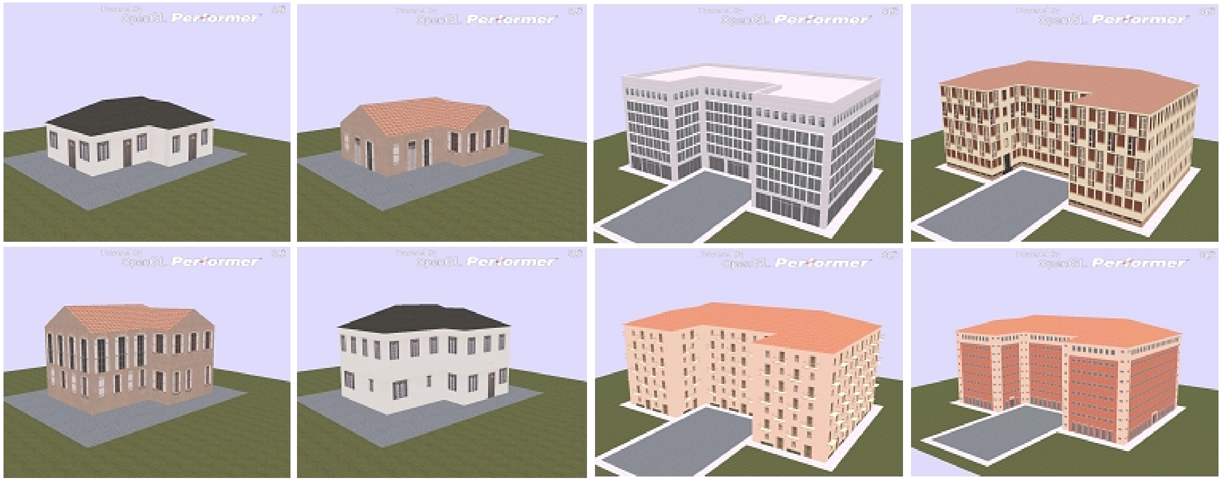
An other key new feature of SE-AGETIM V2 product is the multi texturing capability. Classically, only one texture is affected to a polygon. In the case of "geo-typical" SE – in the SEDRIS acceptation, it means close to reality but not the ground truth - it is not affordable to have the geo-specific texture, in the best resolution, for all the SE. As a consequence, generic physically classified texture, extracted from a pre generated library of classified materials, may be used. The classical drawback of this approach is the self-repetition effect that is prejudicial to realism. The multi-texturing enables to combine several textures for a common surface or polygon. This multi-texturing capability is fundamental to fight the previous problem as illustrated here after, first a terrain without any multi texturing (self repetition effect) and a same multi texture for the whole terrain (variability effect):



3. BUILDING MODELING

3.1. 3D buildings automatic generation

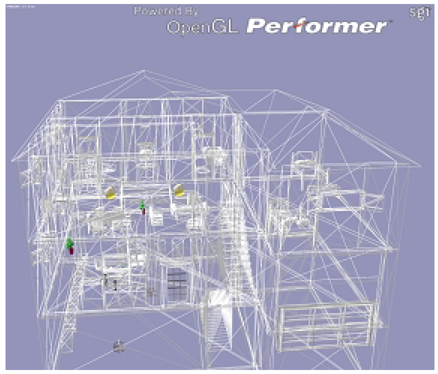
SE-AGETIM V2 includes dedicated algorithms to automatically generate 3D buildings, directly extruded from their footprints. The footprints are typically acquired using urban feature vector files or paper maps, or using airborne picture, possibly geo-referentiated via the GIS included in SE-AGETIM V2. The algorithm is based on a "straight skeleton" method with special arrangements to allow several different wall and roof styles to be generated, and taking into account level of details and conforming to the terrain. This is illustrated here after with 4 representations of 1 common footprint of a house and 4 representations of 1 common footprint of a building:



This SE-AGETIM-V2 functionality enables to rapidly generate a whole urban area fully integrated in the terrain as shown in the picture here after:

3.2. 3D buildings indoor modeling

Besides, SE-AGETIM V2 includes a new module SE-AGETIM-INDOOR that enables to generate the inner parts of buildings, inheriting the multi sensor capabilities of CHORALE, including floors and indoor walls generation, door and windows apertures, staircases elevation, furniture positioning. A special attention is paid on wall coating and physical material assignment. An other interesting feature is the management of underground rooms like ceiling.
The GUI enables to take into account a geo specific plan. Using the connection to the 3D buildings automatic generation explained in the previous paragraph, the tool automatically can generate the whole building including inner parts as illustrated her after:

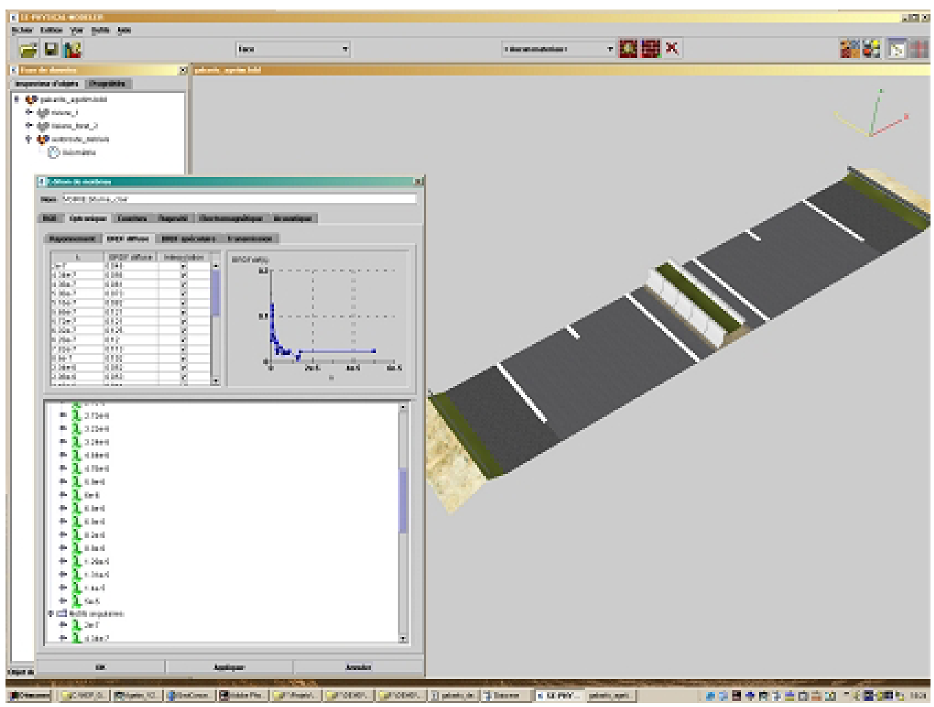


4. MULTI SENSOR APPROACH

A unified IR+EM+AC approach of physical material management enables to combine different sensor of different domains on the same scene. To perform it, CHORALE new release includes a new multi domain material format and associated API. Two basic difficulties have driven this strategy:

- the number of material combinations grows exponentially with the number of domains. So does the number of duplicated data. For example, the material “red painting on wood” has the same optronic features as “red painting on concrete”. It is useless to duplicate the spectral BRDF and emissivity of “red painting” on all the materials that are painted in red. On the other hand, for thermal computations, it is important to know if the material under the “red painting” is “wood” or “concrete”.
- for a given material, due to the lack of data (measurements) for a specific spectral band, the user may select a replacement material with similar features. As a consequence, for another spectral band, the features of the substitutive material and the original material are not necessarily coherent.

To share this new type of multi domain materials, CHORALE tools have been updated, especially the SE-PHYSICAL-MODELER that enables to create and assign the physical materials to the templates associated to the SE-AGETIM patterns, for profiling and elevating features. The figure below shows the multi domain assignment of a high way template:



5. APPLICATION TO URBAN WAR

A key application of this new feature of CHORALE is the urban combat. SE-AGETIM V2 is used to model very rapidly a given site. Concerning the target building, SE-AGETIM-INDOOR enables to create a credible inside environment. CHORALE sensor models have been simplified to run in real time and simulate a credible performance of new generation sensor (Light Intensifiers, Ultra wide band …). The general objective is to assess new sensor new ways of use for time for various environment. An other promising way is the time sensitive targeting.

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